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THESIS

VERTICAL REPLENISHMENT AIRLIFT PLATFORM FOR THE 21ST CENTURY: AN ANALYSIS USING THE SIMULATION MOBILITY MODELING AND ANALYSIS TOOLBOX (SMMAT)

by

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VERTICAL REPLENISHMENT AIRLIFT PLATFORM FOR THE 21ST CENTURY: AN ANALYSIS USING THE SIMULATION MOBILITY MODELING AND ANALYSIS TOOLBOX (SMMAT)

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This thesis documents the design and implementation of a vertical replenishment simulation using the object oriented programming language MODSIM II written by CACI Products Company of La Jolla, California and the Simulation Mobility Modeling and Analysis Toolbox written by Professor Mike Bailey of the Naval Postgraduate School, Monterey. Using data generated by this simulation, performance parameters are evaluated for three candidate helicopters (the CH-46E, the CH-60, and the KMAX) under consideration to replace the CH-46D logistics support aircraft currently in use by the U.S. Navy. A quantitative and qualitative evaluation of the most promising helicopter follows this analysis.

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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EXECUTIVE SUMMARY

Vertical replenishment (VERTREP) is a logistic support operation in which Naval helicopters pickup palletized cargo from ships of the Combat Logistics Force and deliver them to combatants at sea. The current naval vertical replenishment helicopter, the CH-46D tandem-rotor helicopter, has been in use for over thirty years and is approaching the end of its service life. Three potential replacements for this helicopter, the CH-46E, the CH-60, and the KMAX aerial truck, have been identified.

In order to measure the performance characteristics of these three helicopters, a computer simulation was created using the object-oriented programming language MODSIM II written by the CACI Products Company of La Jolla, California and the Simulation Mobility Modeling and Analysis Toolbox (SMMAT) written by Professor Mike Bailey of the Naval Postgraduate School, Monterey. The computer program simulates a two helicopter delivery of two hundred pallets of cargo to seven ships of an aircraft carrier battlegroup. Each pallet weighs, on average, 2,000 pounds plus or minus 1,000 pounds.

The CH-46E is an improved model of the CH-46D used by the U.S. Marine Corps for their medium lift transportation

requirement. The CH-60 is a marinized version of the Army Blackhawk helicopter. Although the CH-60 is a tail-rotor helicopter, it is assumed capable of conducting vertical replenishment flight comparable to the tandem-rotor CH-46E and KMAX helicopters. The KMAX aerial truck is an external lift helicopter designed originally to support civilian logging operations. Both the CH-46E and CH-60 have internal and external cargo transportation capabilities, while the KMAX can be used only in the external cargo transportation mode.

The simulation is used to gather statistical data for six helicopter performance measurements: elapsed time to complete delivery, fuel consumed, number of trips between ships, total nautical miles traveled, mean number of pallets per delivered lift, and mean weight of pallets per delivered lift. The last two performance measurements were considered most significant.

Analysis of the data produced by this simulation show that the CH-60 helicopter can transport a measurably greater number of pallets per lift, with greater mean weight, than the KMAX helicopter. Both the CH-60 and the KMAX perform the vertical replenishment mission more capably than the CH-46E. When the CH-60 and KMAX were teamed with the CH-46E (one CH-46E and one CH-60 versus one CH-46E and one KMAX), both

teams transported statistically equivalent quantities of cargo.

While the quantitative analysis provided by this project supports both the CH-60 and KMAX against the CH-46E in the vertical replenishment mission, other qualitative performance criteria favor selection of the CH-60. Because of the CH-60's internal personnel and cargo transportation capability, it can perform other logistics support missions such as pickup and delivery of passengers, mail, and cargo within an aircraft carrier battlegroup and search and rescue support for Marine Corps amphibious assault operations at sea.

I. INTRODUCTION

A. LOGISTICS DOCTRINE

According to Naval Logistics Doctrine [Ref. 1]

> The ability to replenish our naval forces at sea enables the United States to maintain its forward presence, and conduct operations of unlimited and uninterrupted duration close to areas of interest. At-sea replenishment encompasses the coordinated movement of passengers, mail, cargo, and bulk liquids for deployed forces as large as a battle group to individual ships and submarines conducting independent operations.

Elsewhere, this same doctrine states [Ref. 2]

> Versatile and reliable systems allow us to take advantage of scheduled and unscheduled opportunities to resupply our forces at sea. Although circumstances may dictate in-port replenishment, the uniqueness and flexibility of naval logistics is best exemplified by replenishment at sea. Using both connected and vertical replenishment operations, we routinely resupply our ships underway. Connected replenishment employs rigs to transfer fuel, stores, and ammunition while one or more ships steam alongside a delivery ship. Vertical replenishment delivers stores, ammunition and other supplies by helicopter. This fast and efficient means of replenishment is conducted daily, around the world, in the same manner in peacetime as in wartime.

B. CURRENT COMBAT SUPPORT HELICOPTER

The Navy's Helicopter Combat Support squadrons, located in Norfolk, VA, San Diego, CA, and Guam, operate a fleet of CH/UH/HH-46D helicopters whose primary mission is logistics support of the combatant and support fleet at sea around the world. Since the mid 1960's, these tandem-rotor helicopters have come to play such an important logistics support role in fleet operations, including vertical replenishment, passenger, mail and cargo flights for ships in the carrier battle group, search and rescue for the Marine Amphibious Readiness Group, and special operations support, that their ability to continue providing a high level of dependable support has been taken for granted.

Over the past thirty years, various maintenance and life cycle extension efforts have been implemented to extend the service life of the H-46D past its original 10,000 hours. Both the Survivability, Reliability and Maintainability (SR&M) program and the Dynamic Component Upgrade program (DCUP) succeeded in replacing and improving nearly every system and component of the helicopter, except for the airframe itself. However, normal attrition continues to reduce the number of airframes in the Navy's inventory to the point where the helicopter combat support community will

become unable to send sufficient numbers of H-46D aircraft to sea. The aircraft simply will not be available.

The U.S. Marine Corps continues its efforts to replace their fleet of CH-46E helicopters with the new V-22 tilt-rotor aircraft. Integration of these aircraft into the USMC medium lift squadrons will allow transfer of excess CH-46E airframes to the Navy's inventory. However, budgetary constraints continue to delay delivery of the V-22, forcing the Navy to look hard at other interim helicopters to supplement the CH-46D fleet.

C. CANDIDATES FOR NEXT COMBAT SUPPORT HELICOPTER

Three candidate helicopters are currently under consideration to augment and/or replace the CH-46D as the Navy's primary combat logistics support helicopter: the CH-46E previously mentioned; the Sikorsky Aircraft Company's CH-60, a marinized version of the Army's Blackhawk helicopter; and the new KMAX aerial truck manufactured by the Kaman Aerospace Corporation. While the CH-46E and CH-60 helicopters both provide internal and external logistics transportation capabilities, the KMAX is designed to provide only external movement of logistics requirements. This design constraint limits the KMAX to vertical replenishment support.

Without the ability to deploy detachments of trained flight and maintenance personnel with two of each candidate helicopter, the next best choice for gathering mission performance data is to build a simple yet realistic computer simulation of a vertical replenishment to a carrier battle group at sea. This thesis project will take the actual and/or proposed flight characteristics of each candidate helicopter and model the delivery of two hundred pallets of air transportable cargo from a Fast Combat Support Ship (AOE1) to the other members of a battlegroup composed of an aircraft carrier (CVN76), two cruisers (CG47 & CG48), a guided missile frigate (FFG7), a destroyer (DD963), and two guided missile destroyers (DDG51 & DDG52). Flight performance data gathered is then used to evaluate the ability of each pair of helicopters to effectively deliver the required logistics support.

II. VERTICAL REPLENISHMENT

A. ORGANIZATION

Naval vessels deployed at sea require a continuous flow of logistics resupply. In addition to ship and aviation fuels, these surface combatants, amphibious vessels and auxiliaries need a wide assortment of provisions, ammunition and ordnance, repair and consumable parts, administrative support items, and personal and official mail delivery. In order to delivery these logistics supplies to the fleet at sea, the U.S. Navy and Military Sealift Command operate an assortment of Combat Logistics Force (CLF) auxiliary vessels, including the Fast Combat Support Ship (AOE-1 and AOE-6 class), the Combat Stores Ship (AFS and T-AFS), ammunition ships, and oilers.

Before the advent of naval helicopters, the Navy conducted all resupply at sea via connected replenishment (CONREP) between the auxiliary and the surface combatant. During the past 30 years, the Navy's Helicopter Combat Support Squadrons have developed and refined another means for delivery of palletized cargo, namely vertical replenishment (VERTREP). Vertical replenishment involves the use of a helicopter, equipped with an external cargo hook,

to pick up palletized cargo from the flight deck of the auxiliary ship and drop it safely onto the flight deck of the receiving customer vessel. By combining vertical replenishment with traditional connected replenishment methods, the efficiency of the CLF vessel is significantly improved.

Vertical replenishment enables the CLF ship to deliver cargo to more than two customers at the same time. During periods of heavy weather and high sea states when CONREP is not considered prudent, VERTREP can be used to deliver all logistics requirements except fuel and exceptionally large or heavy items (such as some types of ordnance and aircraft engines). In addition, when fleet units are operating together at anchorage or not otherwise underway, VERTREP can be effectively employed.

B. PREPARING FOR VERTICAL REPLENISHMENT OPERATIONS

The process of organizing and conducting vertical replenishment is a straight forward affair, involving coordination between the CLF's supply and deck department, the helicopter detachment's officer-in-charge, and the customer vessels. Cargo scheduled for delivery by the CLF ship, marked by specially colored label for the customer ship, is moved from storage holds to the main decks and

flight deck for preparation for VERTREP delivery. These supplies are placed on standard wooden or metal 40"X48" pallets, which are weighed and grouped together for netting. On the flight deck, a nylon reinforced cargo net is spread out and the palletized cargo is placed in the middle. Drawing together the four ends of the net, a connecting leg joins the net to a 10-15 foot pole pennant. If size and weight considerations allow, two pallets may be stacked on top of each other and connected as one VERTREP lift.

Once the pallets are prepared for VERTREP, they are grouped together on the flight deck. Normally begun the day before the scheduled delivery (for non-perishable cargo), this process completes cargo prestaging before aviation operations commence. All remaining cargo is prestaged on the main decks and/or helicopter hangars during the scheduled delivery and moved to the flight deck as space allows.

The helicopter detachment officer-in-charge promulgates a vertical replenishment plan to all customer ships during the day before the operation begins. This plan tells the customer when to expect delivery of the first load, and which of two helicopters to expect (by helicopter tail number or call sign). Customer ships are assigned stationing positions around the delivery ship, within 500 to 1000

yards. This close proximity enables the helicopters to deliver cargo at a rapid pace.

C. HELICOPTER OPERATIONS DURING VERTREP

At the commencement of VERTREP operations, both helicopters are airborne and, if possible, topped off with fuel. The scheduled customer ships are at flight quarters and show a green deck signal for commencement of deliveries. The first helicopter flies directly to the delivery ship's flight deck, where a flight deck hookup man is standing with the palletized cargo's pole pennant in hand. In the aft cabin of the helicopter, an aircrewman is positioned at the rescue hatch containing the external cargo hook. This opening enables the aircrewman to see underneath the helicopter to the flight decks of both delivery and customer ships. Combining visual cues and verbal signals from this aircrewmen, the pilot hovers low over the hookup man who places the pole pennant's looped end onto the helicopter's external cargo hook. Once the hookup man is clear, the aircrewman gives the pilot verbal direction for lifting the palletized cargo vertically off the flight deck. This is done so that no other cargo is tipped over or otherwise damaged. Once clear, the pilot enters forward flight and flies directly to the customer's flight deck. At this time,

the second helicopter begins its approach to the delivery ship for VERTREP pickup.

When the helicopter with an external lift (the burdened helicopter) arrives at the customer ship's flight deck, the pilot executes a high hover over the cargo dropping zone, again relying on verbal directions from the aircrewman. Properly executed, the drop of cargo onto the customer's flight deck leaves as much open flight deck space as possible for delivery of subsequent lifts. When the flight deck of the customer ship is full of cargo, the ship suspends flight operations (by signaling red deck status) and clears the flight deck of cargo. Flight deck personnel on smaller surface combatants (not equipped with electric forklift trucks) break down and remove palletized cargo lifts by hand, or move the pallets off the flight deck with the aid of a manual pallet jack. Larger ships equipped with forklift trucks attempt to clear loads between helicopter deliveries, but may still require suspension of VERTREP from time to time to complete clearing their flight deck.

When cargo is cleared from the customer's flight deck, the wooden or metal pallets, nets, connecting legs and pole pennants are assembled together into a pallet of retrograde to be returned to the delivery ship. This retrograde must be

returned to the CLF ship so that remaining pallets of cargo can be prepared for VERTREP delivery.

When vertical replenishment operations are ongoing, using two or more helicopters, some other aviation capable ship should be made available to provide periodic refueling services to the aircraft. This keeps the delivery ship open for continued VERTREP pickups and return of retrograde. The best solution is to use one of the customer ships equipped with more than one landing spot, such as an aircraft carrier or amphibious assault ship. Such ships can land and service one helicopter while receiving VERTREP deliveries from the other helicopter.

Return of the last retrograde load to the CLF ship completes the operation, pending the safe return and recovery of both VERTREP helicopters.

D. CONSIDERATIONS FOR REPLACEMENT VERTREP HELICOPTER

1. Background

The Boeing Vertol CH/HH/UH-46A/D is a tandem-rotor helicopter, meaning that it uses two main counterrotating rotors, mounted fore and aft on top of the fuselage, to provide both lift and directional control. This rotor design enables the H-46 to maneuver safely and effectively in all crosswind and tailwind conditions while transporting

external cargo between ships. Its aerodynamic versatility has made the H-46 the best helicopter asset for this unique fleet support mission. In addition, the large interior cabin, capable of loading and unloading up to five pallets of cargo, seating fifteen or more passengers, or holding a large quantity of loose boxes and mail, has made the H-46 ideal for the passenger, mail and cargo (P/M/C) mission important to the carrier battlegroup's logistics coordinator.

The first model of the H-46 provided to the Navy in the mid-1960's, the HH-46A, was designed for a service life of up to 10,000 flight hours. During the following 30 years, several service life extension programs, such as the Survivability, Reliability and Maintainability (SR&M) program, and the Dynamic Component Upgrade (DCUP) program, essentially improved, enhanced and/or replaced every major component of the H-46 except the airframe itself. Yet, due to the normal attrition rate facing any aging helicopter, the number of remaining H-46D aircraft available to meet future fleet logistics requirements is rapidly falling below the bare minimum. In addition to VERTREP and P/M/C services, the Helicopter Combat Support squadrons also use the H-46 for search and rescue (SAR) support for Marine Corps amphibious forces assigned to Marine Amphibious Readiness

Groups. The three candidate replacement helicopters under consideration for short term augmentation and long term replacement of the current fleet of H-46D helicopters are the Boeing Vertol CH-46E, the Sikorsky CH-60, and the Kaman KMAX helicopters.

2. H-46E

While the Navy has used the H-46A/D for helicopter combat support, the Marine Corps has relied on its fleet of CH-46E helicopters for execution of its medium lift troop and cargo transportation requirement. Recognizing during the late 1970's their own need for a replacement helicopter, the Marine Corps aggressively sought acquisition of a fleet of tilt-rotor V-22 Osprey aircraft. Upon receipt of the V-22 fleet, the Marine Corps would release excess CH-46E aircraft to the Navy for augmentation of its H-46D fleet.

Engineering enhancements to the CH-46E have increased its fuel capacity from roughly 2500 pounds of JP-5 to nearly 4500 pounds. Its maximum gross weight is greater than the CH-46D by several hundred pounds, and it carries the more powerful General Electric T58-GE-16 turboshaft engines. Even with these and other improvements, the CH-46E is an aging airframe, with a dwindling supply of reliable repair and replacement parts, and high maintenance overhead costs.

Political and budget reduction realities have repeatedly delayed scheduled production and delivery schedules for the V-22. Current projections do not show employment of this aircraft within its first Marine Corps squadron before the year 2000. Meanwhile, no CH-46E aircraft are available for use within the Navy's helicopter combat support squadrons.

3. CH-60

The second candidate aircraft is the Sikorsky Aircraft CH-60 helicopter. Responding to the requirements expressed by the Navy, Sikorsky proposes combining elements of the Army's Blackhawk (UH-60B), the Navy's Seahawk (SH-60B/F) and the VH-60 into an airframe specially designed and equipped for logistics and utility support. The internal cabin would be configured to transport up to 15 passengers, or up to two standard pallets of cargo. The existing H-60 rescue hatch located in the floor of the aft cabin would be enlarged to 18"X18" to give the aircrewman expanded visibility for VERTREP coordination. The external cargo hook, combined with the helicopters' lift capacity, would enable the pilot to lift up to 6,000 pounds of cargo on a 90°F day. Engineering similarities with existing SH-60 aircraft already employed within the fleet reduce the additional support costs

associated with adding this airframe to the Navy's aircraft inventory.

The most significant factor against the CH-60 is its tail-rotor design. Historically, the sidewind and tailwind restrictions inherent in tail rotor helicopters have put them at a distinct disadvantage against tandem-rotor helicopters performing the VERTREP mission. Normal approach procedures for tail-rotor helicopters traditionally have required relative winds within 30 degrees of the helicopter's forward fuselage. Winds outside this envelope are thought to exceed the tail rotor's ability to maintain directional control. Sikorsky is convinced that the increased aerodynamic performance of the CH-60 would allow it to fly in crosswind and tailwind conditions similar to those acceptable to tandem-rotor helicopters. Preliminary flight tests of HH-60 helicopters by senior aviators in the VERTREP community look very promising.

In addition, the high nose attitude of the H-60 helicopter when transitioning to a hover increases cycle time within the VERTREP pattern. Sikorsky plans to modify the pilot cabin area to increase forward and sideward visibility. For the purposes of this project, I assume that the CH-60 helicopter could be flown in a manner similar to

other proposed tandem-rotor helicopters in the performance of vertical replenishment.

4. KMAX

The most unusual entry into the vertical replenishment helicopter competition is the KMAX aerial truck designed and built by the Kaman Aerospace Corporation. Originally designed to provide external lift capacity to the logging industry, Kaman proposes to lease a package of aircraft, flight and maintenance personnel, and maintenance support to the Navy for use onboard CLF ships.

The KMAX is a single piloted, single-engine, tandem-rotor helicopter whose rotors are mounted side-by-side over the main engine and transmission area. Its light weight and simplified engineering design enable the KMAX to lift up to 6,000 pounds of external cargo while significantly reducing the rate of fuel consumption per flight hour. However, the KMAX has essentially no internal cargo capacity, and could not be used to transport passengers, mail or internal cargo, or provide SAR support. KMAX is only suited for the vertical replenishment mission.

In the vertical replenishment pattern, the pilot relies on verbal recommendations from the aircrewman (positioned at the hell hole) in order to avoid obstacles and position the cargo hook vertically over the cargo load. The design of the

KMAX helicopter, as a single-piloted aircraft without passenger or aircrewman carrying capacity, removes this source of helicopter positioning and safety information from the VERTREP pilot. In heavy seas with significant pitch and roll of the flight deck, this loss of crew coordination could place the KMAX pilot at a big disadvantage. However, for the purposes of this simulation analysis, I will assume that proper training and flight experience will allow the single-piloted KMAX to perform the VERTREP mission with the same effectiveness as the CH-46E and the CH-60.

E. COMPARING POTENTIAL VERTICAL REPLENISHMENT HELICOPTERS

1. Performance Parameters

In order to make a logical comparison of the three candidate replacement VERTREP helicopters, a number of objective performance parameters must be defined. The goal of vertical replenishment is the safe and expeditious delivery of logistics supplies and materials to ships at sea. A number of considerations come into play when attempting to maximize this expeditious delivery. An expeditious delivery is one completed in the shortest period of time, both overall for the entire battle group and for each individual ship. Two factors determine how fast a

helicopter can deliver the pallets required by a customer ship: flight endurance and cargo lift capacity.

Helicopters burn their supply of fuel at a rate determined by their gross weight, speed, altitude and environmental conditions. For helicopters with the same fuel consumption rate, the one that can carry more fuel between refuelings can continue flight for a longer period. The cargo lift capacity of a given helicopter (for standard day conditions) is calculated as the minimum of the difference between the aircrafts' maximum gross weight and the sum of its operating weight (empty or basic weight + crew weight + mission equipment weight) and its fuel load; or the capacity of the external cargo hook. For example, for a helicopter with an external cargo hook capacity of 6,000 pounds, a maximum gross weight of 24,000 pounds, and an operating weight plus fuel weight of 17,500 pounds, the cargo lift capacity would be the minimum of (24,000 - 17,500 = 6,500 pounds) or 6,000 pounds. Since the difference between maximum gross weight and operating weight plus fuel weight increases as the aircraft burns its store of fuel, the cargo lift capacity may also increase as the flight proceeds. For a standard vertical replenishment cycle between the delivery ship and a number of customer ships, helicopter speed is not an important consideration since all ships are relatively

close together (less than 1 nautical mile). For the purposes of this simulation, the average speed of all helicopters is held constant at 40 nautical miles per hour.

2. Projected Pallet Weights

Pallets prepared for VERTREP delivery may represent an assortment of logistics support, from frozen and chill provisions to ordnance to repair parts. Although each VERTREP operation is unique, a typical representation of pallet weights may place the mean at 2,000 pounds, uniformly distributed across the range 1,000 pounds to 3,000 pounds. This assumption creates pallets of sufficient weight diversity that a customer could receive as many as four pallets per delivered lift. This is consistent with actual fleet practice.

3. Pallets Per Lift and Weight Per Lift

Theoretically, the flight deck officer on the delivery ship could group individual pallets destined for each customer ship in such a way that the helicopter transports as many pallets as possible on each delivery trip. At the beginning of the helicopter's flight, loaded with a full load of fuel, its cargo lift capacity would necessarily be less than one hour later when half of its fuel was consumed. Heavier lifts may be transported as the helicopter

approaches its refueling time. In fact, VERTREP pilots use this factor to plan the lift of heavy cargo just prior to refueling. The simulation should gather statistics on the mean number of pallets transported per lift and mean weight of grouped pallets per lift. Helicopters that can transport greater numbers of pallets per lift, and heavier weights of cargo per lift, could then be considered more effective in the vertical replenishment role.

4. Combinations of Helicopters

In addition to evaluation of vertical replenishment operations with two of each type of helicopter, I will gather statistical information for combinations of helicopters. Regardless of the long term solution to the Navy's medium lift helicopter requirement, a number of Marine Corps CH-46E helicopters will come into the Navy's inventory as the tilt-rotor V-22 aircraft is received into USMC squadrons. The Navy may be faced with deploying combat support detachments with one CH-46E and one other helicopter, either the CH-60 or the KMAX. Simulations of these possible aircraft mixes provide a quantitative measure of relative performance.

III. THE MODEL

A. SIMULATION MOBILITY MODELING AND ANALYSIS TOOLBOX (SMMAT)

1. SMMAT Background

The Simulation Mobility Modeling and Analysis Toolbox (SMMAT) was designed and written by Professor Mike Bailey of the Naval Postgraduate School's Operations Research department. In 1994, LT Tim Wilson used the SMMAT to create a helicopter transportation model simulating passenger, mail and cargo (P/M/C) movement between ships in a carrier battlegroup. Using LT Wilson's model as a framework for refinement and improvement, the vertical replenishment simulation model described in this chapter was produced.

2. Junction, Transporter and Cargo Objects

Written in the MODSIM II computer language, SMMAT uses object oriented programming to manipulate a series of junction, transporter and cargo objects. A junction is any ship, aircraft, or base that can receive another junction, transporter or cargo object. A transporter is any ship or aircraft that can move from junction to junction. A cargo object is moved from junction to transporter, then from transporter back to junction. All transporters are also

junctions and all junctions are transporters. For example, in this simulation, all ships and helicopters are junctions, because ships can receive helicopters and helicopters can receive and deliver cargo. All helicopters are transporters, because they move from junction to junction. The ships do not act as transporters in this simulation, although they possess the necessary fields and methods.

The basic junction object is the ***GrossMovementObj***, with fields and methods providing basic movement characteristics. Four descendant objects come from it: ***BasTransObj*** gives fields and methods necessary for basic transportation functions; ***BasJunctObj*** gives additional fields and methods for handling transporters; ***JunctBuildObj*** handles the creation of cargo, transporter and cargo objects; and ***JunctObj*** is defined as the descendant of the previous four objects.

3. Master Lists of Objects

SMMAT uses a series of lists and queues to transform files of input data into the appropriate junction, transporter and cargo objects, assign the transporters and cargo objects to specific initial junctions, and maintain status of delivery from the Combat Logistics Force (CLF) ship (in this simulation a Fast Combat Support Ship) to the

designated customer ships. After initial creation of all junction, transporter and cargo objects, the model maintains ***JMasterList*** (a list of the name and junction object associated with each ship), ***TotJunctList*** (a similar list which also includes the helicopter junctions), and ***CMasterList*** (a master list of each cargo object with status of delivery completion). In addition, the CargoList queue associated with each junction and transporter holds cargo objects either scheduled for delivery or actually delivered. Initially, all scheduled cargo is placed in the AOE's CargoList with fields giving named destination junction, priority and completion status.

4. Initial Creation and Placement of Objects

Transporter objects created by the model are placed in an initial queue within either the IdleList or HoverList of the transporter's home junction, the AOE. Since the vertical replenishment model creates two helicopter transporters, one helicopter created enters the AOE's IdleList while the second enters the HoverList. Appendix A lists the weight, airspeed and performance data used for each helicopter simulated in the vertical replenishment model.

During initial creation of cargo objects, a randomizing process using a UniformReal function of MODSIM II calculates

the weight of each pallet, using a mean weight of 2,000 pounds and a range of 1,000 to 3,000 pounds. The resulting distribution of pallet weights enables the simulation's LoadCargo method to find up to four pallets of cargo for a given lift transported between delivery and customer ships, depending on cargo hook capacity and helicopter fuel onboard.

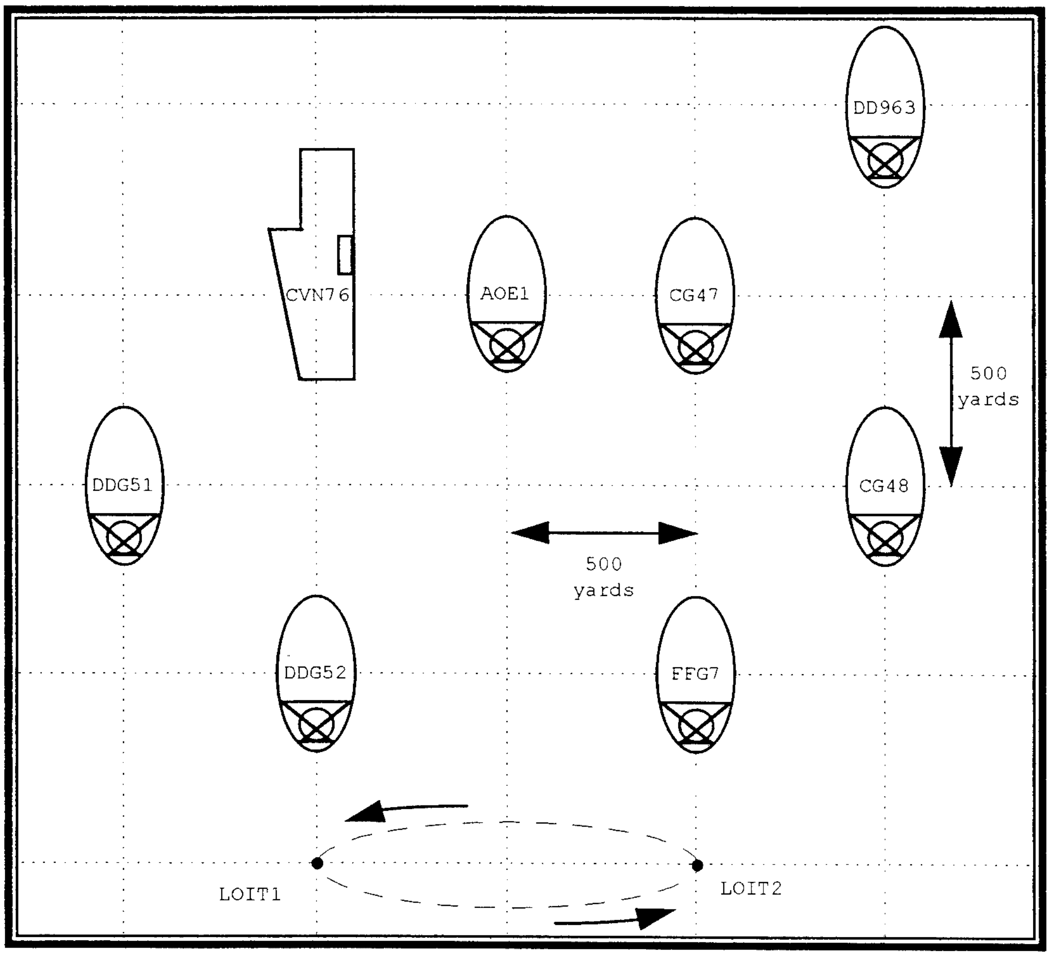

Figure 1. Location of Junctions in VERTREP Pattern

Figure 1 shows the location of all junctions used in the vertical replenishment simulation. Notice that there are two additional junctions provided, named LOIT1 and LOIT2. These junctions will be explained in later sections of this chapter.

B. VERTICAL REPLENISHMENT SIMULATION PROCESS

1. Initial Placement of Pallets

In this simulation, the AOE holds 200 pallets of external cargo scheduled for delivery to seven naval combatants as follows: 50 pallets for CVN76, 30 pallets for CG47, 30 pallets for CG48, 30 pallets for DD963, 20 pallets for FFG7, 20 pallets for DDG51, and 20 pallets for DDG52. These seven customer ships are prioritized as above, from CVN76 to DDG52. One helicopter services all seven customer ships, while the other services all but the CVN. Mean weight of each pallet is 2,000 pounds, uniformly distributed between 1,000 and 3,000 pounds. Up to four pallets could be grouped into each external lift, depending on pallet weight and the helicopter's allowable load each trip.

2. Importance of Destination Junction

The VERTREP helicopter always needs a destination junction, defined either as a ship with cargo to pickup or

drop, or a point in the delta pattern flown aft of the ship formation when all ships are busy. Once a junction receives a helicopter, it must execute all assigned methods and hand the helicopter off to another junction. This keeps the simulation going, moving cargo objects from ship to ship, and gathering appropriate statistics.

3. Potential Delays During Vertical Replenishment

The overall goal of the vertical replenishment simulation is to move each pallet of simulated cargo from the delivery ship (the AOE) to each of the customer ships in priority order. There are two potential events which will delay continued pickup and delivery of pallets. These events are a full flight deck on the customer ship, and low fuel on the delivery helicopter. When the ship receiving pallets via VERTREP receives ten pallets, her flight deck is considered to be full and further receipt of pallets must be suspended while the crew removes the cargo from the flight deck. During this time, the helicopter(s) transporting pallets must continue VERTREP at the next highest priority customer ship, or enter the aft delta pattern. When the helicopter's fuel onboard has been reduced to such a level that further deliveries between ships would reduce the fuel level below the minimum fuel level, that helicopter must go to the CVN and land for refueling. During the refueling, this

helicopter is prevented from participating in further transfer of pallets.

4. Aft Delta Pattern

When there is still external cargo due for delivery to its destination ship, but all these ships have suspended flight operations while clearing pallets from their flight decks, the helicopters may temporarily have no valid ship to fly to. In this case, the helicopter enters an aft delta pattern where it remains until a ship resumes flight operations. The aft delta pattern is defined by two junctions, LOIT1 and LOIT2. The implementing methods will be further described below.

5. Helicopter Refueling Ship

Once the VERTREP simulation commences, the delivery ship should not be used to refuel either of the cargo transporting helicopters. Instead, another ship in the formation (in this case the CVN), preferably having a multi-spot helicopter landing and servicing capability, should be used to periodically refuel the helicopters. This enables the delivery ship, in this case the AOE, to continue sending pallets to customer ships using the second operating helicopter. In addition, an open flight deck on the AOE facilitates staging of additional pallets scheduled for

transfer. Pallets which had not been prestaged before the commencement of VERTREP operations, such as fresh fruits, vegetables and daily products, must then be staged on the flight deck after flight operations begin.

6. Helicopters Launched from AOE

When the simulation begins, the helicopter assigned to service the CVN loads its first group of pallets (a "lift") from the AOE, and departs to make its first delivery. Then the other helicopter loads its first cargo lift for the CG47 and makes its departure. The rest of this chapter describes the methods used to simulate each portion of the remaining VERTREP deliveries within the battlegroup.

C. VERTREP CYCLE

1. Departing the Junction

When the helicopter begins to depart the ship, the simulation calls for a 15 to 60 second delay to simulate lifting the external load off the flight deck, stabilizing over the deck before transitioning to forward flight, and compensating for the effects of crosswinds and the pitch and roll of the flight deck. The total number of trips the helicopter makes between ships is then incremented.

2. Transiting to the Destination Junction

The simulation calculates the distance between the previous ship's location and the next ship's location, divides this distance by the helicopter's mean airspeed (0.67 nautical miles per minute), and finds the time in minutes that the simulation must wait before the helicopter arrives at its destination. The simulation waits this number of minutes.

3. Destination Junction Receives the Transporter

When a ship is told to receive an arriving helicopter, it first checks to see if the flight deck is clear of the other helicopter. If there is another helicopter servicing the ship, the arriving helicopter enters a temporary orbiting pattern. When the ship launches the first helicopter, the helicopter in the orbiting pattern is received.

a. *Dock*

The helicopter's movement is delayed for a uniformly distributed period of 15 to 60 seconds to simulate the final approach to a hover, centering of the external cargo or cargo hook over the hover or landing spot, and to compensate for the effects of crosswinds and the pitching and rolling of the ship's flight deck.

b. Unloading the External Cargo

(1) Unloading the pallets. If there is external cargo to be delivered, the helicopter's movement is delayed for 15 seconds. At this time, each of the pallets grouped together into the delivered cargo lift is transferred from the helicopter's CargoList to the receiving ship's CargoList. The cargo's priority is increased to some large integer value (to show that it has been delivered), the cargo's assigned transporter is changed to NILOBJ, the cargo's current junction value is changed to the name of the customer junction, the cargo's DONE boolean value is changed to TRUE, and the number of pallets on the ship's flight deck is incremented.

(2) Check to see if ship's flight deck is full. Once all pallets from the delivered external lift are transferred to the customer ship, the ship checks to see if the total number of pallets on deck exceeds ten. If so, further receipt of external lifts is suspended and the Red Deck boolean value is triggered, the ship is instructed to clear the pallets off the deck, and the number of pallets on the deck is reduced by ten.

(3) Clear pallets off the flight deck. For all ships except the CVN, a delay is calculated using a

uniform distribution between nine and nineteen minutes. For the CVN, a delay is calculated using a uniform distribution between two and eight minutes. Although most aircraft carriers routinely continue receipt of VERTREP without periodic delays for clearing the deck, this portion of the method enables the simulation to proceed uniformly while processing a delay for creation of the pallet of retrograde which must be returned to the AOE. Since delivery of pallets continues to other ships while the CVN's deliveries are temporarily suspended, the statistics gathered by the simulation are still valid. Once the delay is complete, a pallet of cargo nets, empty wooden or metal pallets, attaching legs, and pole pennants is created and placed on the ship's CargoList for delivery back to the AOE. The ship resumes flight operations and the Green Deck boolean value is triggered.

(4) Has all cargo been delivered? At this point, the simulation program examines each cargo object listed in the CMasterList listing to see if every pallet of cargo has been delivered to its destination junction. If so, the simulation is shutdown and final statistics are evaluated.

(5) Update the helicopter's fuel status. If the helicopter is located at the CVN, and its Low Fuel

boolean value has been previously triggered, the helicopter stops for refueling.

(6) Refueling the helicopter. First, the helicopter's fuel status is updated. Each helicopter keeps track of the simulation time when its fuel on hand was last updated. This time is compared to the current SimTime, and the difference is multiplied by the helicopter's fuel burn rate to find the number of pounds of JP-5 consumed. This value is subtracted from the number of pounds of JP-5 that the helicopter has onboard.

The amount of fuel needed is calculated by subtracting the current fuel onboard from the helicopter's maximum fuel capacity. A refueling delay is then calculated. The pressure refueling equipment of the CVN is estimated capable of delivering 484 pounds of JP-5 to the helicopter per minute. By dividing the amount of fuel needed by 484.0, the number of minutes required to receive fuel can be calculated. In addition to the actual time required to receive fuel, an additional ten minutes delay is provided to account for the time needed to have the flight deck crew tie the helicopter to the flight deck, attach the refueling hose, get a good fuel sample, remove the refueling equipment after refueling, and remove the tiedown chocks and chains. This delay also accounts for the time required for the

helicopter's aircrewmen (if assigned) to conduct aft station security checks of dynamic components.

After refueling, the quantity of fuel onboard is increased to the maximum fuel capacity, the Low Fuel boolean is changed to FALSE, and the helicopter's fuel status is once again updated to account for the fuel consumed while refueling was conducted.

(7) Finding the helicopter's next destination. At this point, the helicopter must find a valid junction to proceed to, either a ship or the aft delta pattern. There are four possibilities for determining the helicopter's next destination: the current ship could have cargo ready for transfer to another ship, another ship in the formation could have cargo ready for transfer, the helicopter could require refueling, or the helicopter could be sent to the aft delta pattern.

(a) Cargo ready on current ship. If the current ship has cargo, either regular palletized supplies or retrograde, it will be held on the ship's CargoList. The helicopter evaluates each cargo object held in the ship's CargoList to see if it still needs to be moved, if it meets the helicopter's weight limitations, if the helicopter services the cargo's destination ship, and whether the cargo's destination ship is currently open for VERTREP

deliveries. When all these criteria are met, the helicopter checks its fuel load to see if it has sufficient fuel to complete the cargo delivery. If not, the CVN is assigned as the helicopter's destination junction. Otherwise, the cargo's destination junction is assigned to the helicopter.

(b) Cargo ready on another ship in formation. If the current ship has no cargo to be transferred, the helicopter checks the CargoLists of all other ships it services to see if there is cargo to be transferred. Again, the helicopter evaluates the Green Deck status of the possible destination, checks to see that there is cargo to be moved, and checks to see that the cargo's destination ship is open for VERTREP deliveries. Of the possible cargo objects found, the helicopter selects the set with the highest priority for delivery, and marks that ship as its next potential destination. Then, the helicopter checks its fuel onboard to see that it has sufficient fuel to complete the delivery. If fuel is needed, the CVN is set as the helicopter's next destination. Otherwise, the previous destination found is set as the helicopter's next destination.

(c) Helicopter needs refueling. As described above, if the low fuel status of the helicopter prevents it from completing potential VERTREP pickups or

deliveries, the CVN is set as the helicopter's next destination.

(d) Aft delta pattern selected as next destination. If there is still cargo to be delivered, but all applicable ships are busy clearing pallets off their flight decks, then the helicopter is given the next destination of NILOBJ (meaning no destination is set). This prepares the helicopter up for later transfer to the aft delta pattern.

(8) Helicopter's next destination set as NILOBJ. After a destination junction is set for the helicopter, the Unload method is completed, and control returns to the ship's Receive Transporter method. If the helicopter has been assigned the destination junction of NILOBJ, it is changed to the junction LOIT1 (the western end of the aft delta pattern). The distance from the current junction to the next junction is calculated and the total nautical miles traveled parameter is updated. At this time, the ship sends the helicopter to the LOIT1 junction of the aft delta pattern.

(a) Implementation of Proceed to Loiter Station 1. Initially, the helicopter is delayed 15 to 60 seconds to simulate the departure from the ship. The distance from the old junction to the next junction is

calculated and the simulation is delayed the appropriate number of minutes. After this delay, the helicopter's current junction becomes the junction LOIT1 and the helicopter's fuel status is updated. Having arrived at the first junction in the aft delta pattern, the helicopter searches for a valid ship junction for its next destination. Since the aft delta pattern holds no cargo objects, the helicopter searches the CargoLists of all ships it services to locate cargo ready for transfer. If the destination junction found is NILOBJ, the eastern end of the aft delta pattern (LOIT2) is marked as the helicopter's next potential destination, a fuel check is executed, and the helicopter's next destination changed to the CVN if refueling is needed. Otherwise, the total number of nautical miles traveled is updated and the helicopter proceeds to the LOIT2 junction. However, if a valid ship has been located, the helicopter updates the total number of nautical miles traveled and departs for its destination ship.

(b) Implementation of Proceed to Loiter Station 2. The steps required in this method are the same as for proceeding to loiter station 1, except that if no valid ship destination is found, and fuel is not required, the helicopter returns to loiter station 1 of the aft delta pattern.

(9) Helicopter's next destination not NILOBJ. If during the current ship's Receive Transporter method a valid ship is found and set as the helicopter's next destination, the helicopter updates the total nautical miles traveled, cargo on the current ship is loaded if appropriate, and the helicopter is told to depart the current ship.

(10) Load method implemented. If the helicopter has been instructed to load cargo located on the current ship, it evaluates each cargo object on the ship's CargoList to see that it is due for transfer, the helicopter services the cargo's destination ship, the cargo meets the helicopter's weight limitations, and each cargo object in the group goes to the same destination. Up to four pallets may be transferred to the helicopter's CargoList grouped together as one external lift. A 15 second delay to the helicopter's movement simulates attachment of the lift to the helicopter's external cargo hook. If a lift is hooked onto the helicopter, the value TripsWithLifts is incremented.

(a) Fits method implemented. Part of the cargo loading method described above involves checking the helicopter's weight limitations to see if another pallet can be included in the external lift. The amount of weight that

a helicopter can carry is limited by its maximum gross weight, its operating weight, and its fuel weight. Operating weight is the sum of the helicopter's basic or empty weight, the weight of the crewmembers, and the weight of all mission equipment. By subtracting the sum of the helicopter's operating weight plus the weight of fuel onboard from the maximum gross weight, the helicopter's payload can be calculated. Environmental conditions are assumed which would allow the maximum payload. If the payload is equal to or less than the helicopter's external cargo hook capacity, then payload weight equals the amount of weight that the helicopter can lift. Otherwise, the lift capacity is limited by the external hook capacity. In addition, no more than four pallets grouped together as two sets of two pallets each can be attached to the external cargo hook. In this configuration, one pole pennant connects each double stacked group of pallets to the hook, for a total of two pole pennants attached.

4. Continuation of VERTREP Simulation

Once the helicopter departs from its previous ship or loiter junction, the process of receiving and launching helicopters from ships, loading and unloading pallets, and gathering statistical information continues until all cargo objects on the CMasterList listing have been delivered. This

is a dynamic process, with new retrograde objects created periodically as supply pallets are delivered. Whether or not all retrograde objects have been created before the end of the simulation, the simulation stops when the last cargo object on the CMasterList is delivered.

D. PERTINENT STATISTICS

For each repetition of this simulation (thirty repetitions total), the following statistics are gathered. The total then is evaluated to provide the mean, standard deviation, and a 95% confidence interval.

1. Elapsed Time

This statistic measures the time required for each set of two helicopters to deliver all pallets of cargo and retrograde between delivery and customer ships in the vertical replenishment formation.

2. Fuel Consumed

This statistic measures the quantity of JP-5 consumed by both helicopters during each repetition of the vertical replenishment simulation. It does not measure fuel required to recover the helicopters on the AOE after the simulation stops.

3. Number of Trips

This statistic measures the number of trips that both helicopters make from one ship to another, to pickup and/or deliver pallets or to refuel. It does not include the trips around the aft delta pattern.

4. Nautical Miles Traveled

This statistic measures the total number of nautical miles traveled by both helicopters in the simulation, including the cycles around the aft delta pattern.

5. Pallets per Lift

This statistic measures the mean number of pallets transported by both helicopters during the simulation. It is calculated by dividing the total number of pallets delivered by the number of trips both helicopters make with external cargo attached to the their cargo hooks.

6. Weight per Lift

This statistic measures the mean weight of cargo lifted during each delivery. It is calculated by dividing the total weight of all pallets delivered by the total number of trips both helicopters make with external cargo attached to the their cargo hooks.

IV. ANALYTICAL PROCEDURES

A. INTRODUCTION

A complete set of thirty vertical replenishment repetitions was simulated using two of each of the following helicopters: the CH-46E, the CH-60, and the KMAX. For the CH-46E, one simulation features a full load of fuel, while another simulation gave each CH-46E a smaller maximum fuel parameter. In addition, simulations were conducted with a team of one CH-46E and one CH-60, and one CH-46E and one KMAX. The following sections describe the analytical procedures used to evaluate the simulation data obtained.

B. SIMULATIONS USING THE SAME HELICOPTER

1. Two CH-46E Helicopters

Since the CH-46E has received an airframes modification which nearly doubles its fuel capacity, the first simulation featured two CH-46E helicopters loaded with 4,488 pounds of JP-5 fuel. Another simulation was conducted with two CH-46E helicopters loaded with the old maximum fuel capacity of 2,421 pounds of JP-5. This comparison is designed to highlight the performance characteristics of the same

helicopter with sharply different flight endurance. Table 1 gives the resulting statistics:

Elapsed Time	Mean	Std Dev	Conf Interval
CH-46E HiFuel	254.93	2.71	1.94
CH-46E LoFuel	148.54	4.29	3.07
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-46E HiFuel	10,191.28	106.31	76.08
CH-46E LoFuel	5,864.14	198.83	142.30
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-46E HiFuel	378.67	18.13	12.97
CH-46E LoFuel	354.43	37.44	26.80
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-46E HiFuel	292.35	45.87	32.83
CH-46E LoFuel	328.48	115.78	82.86
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E HiFuel	1.46	0.10	0.05
CH-46E LoFuel	2.05	0.17	0.11
Weight/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E HiFuel	2,780.65	130.02	93.05
CH-46E LoFuel	3,917.86	275.27	197.01

Table 1. Summary Data for CH-46E (High and Low Fuel).

These statistics clearly show that the pair of CH-46E helicopters with a reduced maximum fuel capacity demonstrate greater effectiveness in the vertical replenishment role. While using less fuel, the CH-46E can transport a greater number of pallets per lift (with a greater weight per lift), and can therefore complete the deliveries in a shorter period of time.

Another method of comparing the performance of these two sets of CH-46E helicopters involves a statistical comparison of the raw data. Using the analysis of variance procedure (ANOVA), we compare the thirty values gathered for each of the six statistics. Appendix B shows the raw data and Appendix C shows the ANOVA analysis for each of the six statistical parameters. Again, the results show clearly that the pair of CH-46E helicopters with the reduced maximum fuel capacity transfers external lifts at a higher rate and completes the transfer in less time.

The remainder of this analysis will consider comparisons between the CH-46E with the lower maximum fuel capacity and the CH-60 and KMAX helicopters.

2. Two CH-60 Helicopters

A simulation was conducted with two CH-60 helicopters. Table 2 gives the resulting statistics:

CH-60	Mean	Std Dev	Conf Interval
Elapsed Time	144.22	4.99	3.57
Fuel Used	5,748.70	205.40	147.00
Number of Trips	288.87	41.37	29.61
Nautical Miles	323.56	119.89	85.81
Pallets/Lift	2.47	0.20	0.14
Weight/Lift	4,712.49	356.49	255.14

Table 2. Summary Data for CH-60.

3. Two KMAX Helicopters

A simulation was conducted with two KMAX helicopters. Table 3 gives the resulting statistics:

KMAX	Mean	Std Dev	Conf Interval
Elapsed Time	144.22	6.77	4.85
Fuel Used	2,285.45	71.92	51.47
Number of Trips	282.20	356.94	25.55
Nautical Miles	319.65	236.03	168.93
Pallets/Lift	2.35	0.14	0.11
Weight/Lift	4,507.07	283.27	202.73

Table 3. Summary Data for KMAX.

C. COMPARISONS BETWEEN GROUPS OF THE SAME HELICOPTER

Armed with the simulation results listed in the previous section, the next step involves a comparison of helicopter performance characteristics between groups of the same helicopter. Therefore, three comparisons are made and a statistical analysis conducted as outlined below between the CH-46E and CH-60, the CH-46E and KMAX, and the CH-60 and KMAX.

1. CH-46E versus CH-60

Table 4 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for two CH-46E helicopters and two CH-60 helicopters.

Elapsed Time	Mean	Std Dev	Conf Interval
CH-46E	148.54	4.29	3.07
CH-60	144.22	4.99	3.57
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	5,864.14	198.83	142.30
CH-60	5,748.70	205.40	147.00
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	354.43	37.44	26.80
CH-60	288.87	41.37	29.61
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	328.48	115.78	82.86
CH-60	323.56	119.89	85.81
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	2.05	0.17	0.11
CH-60	2.47	0.20	0.14
Weight/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	3,917.86	275.27	197.01
CH-60	4,712.49	356.49	255.14

Table 4. Summary Data for CH-46E versus CH-60

These statistics clearly show that the pair of CH-60 helicopters demonstrate greater effectiveness in the vertical replenishment role. The CH-60 can transport a greater average number of pallets per lift, and the mean weight per lift is 20.28% greater than the CH-46E helicopter.

Using the analysis of variance procedure (ANOVA), we compare the thirty values gathered for each of the six

statistics. Appendix D shows the raw data and Appendix E shows the ANOVA analysis for each of the six statistical parameters. Again, the results show clearly that the pair of CH-60 helicopters transfers a greater number of pallets per lift with greater weight per lift than the CH-46E and completes the transfer in less time.

2. CH-46E versus KMAX

Table 5 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for two CH-46E helicopters and two KMAX helicopters.

Elapsed Time	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	148.54	4.29	3.07
KMAX	144.22	6.77	4.85
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	5,864.14	198.83	142.30
KMAX	2,285.45	71.92	51.47
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	354.43	37.44	26.80
KMAX	282.20	35.69	25.55
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	328.48	115.78	82.86
KMAX	319.65	236.03	168.93
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E	2.05	0.17	0.11
KMAX	2.35	0.14	0.11

Weight/Lift	Mean	Std Dev	Conf Interval
CH-46E	3,917.86	275.27	197.01
KMAX	4,507.07	283.27	202.73

Table 5. Summary Data for CH-46E versus KMAX.

These statistics show that the pair of KMAX helicopters demonstrates greater effectiveness in the vertical replenishment role over the CH-46E. The large reduction in fuel consumed can be attributed to the single engine configuration of the KMAX over the CH-46E. Number of pallets per lift and mean weight per lift is significantly improved by the KMAX (mean weight per lift for KMAX is 15.08% better with KMAX than with the CH-46E).

Using the analysis of variance procedure (ANOVA), we compare the thirty values gathered for each of the six statistics. Appendix F shows the raw data and Appendix G shows the ANOVA analysis. Again, the results show clearly that the pair of KMAX helicopters transfers more cargo, by number of pallets per lift and weight per lift, than the CH-46E and completes the transfer in less time.

3. CH-60 versus KMAX

Table 6 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for two CH-60 helicopters and two KMAX helicopters.

Elapsed Time	Mean	Std Dev	Conf Interval
CH-60	144.22	4.99	3.57
KMAX	144.22	6.77	4.85
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-60	5,748.70	205.40	147.00
KMAX	2,285.45	71.92	51.47
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-60	288.87	41.37	29.61
KMAX	282.20	35.69	25.55
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-60	323.56	119.89	85.81
KMAX	319.65	236.03	168.93
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-60	2.47	0.20	0.14
KMAX	2.35	0.14	0.11
Weight/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-60	4,712.49	356.49	255.14
KMAX	4,507.07	283.27	202.73

Table 6. Summary Data for CH-60 versus KMAX.

These statistics show a modest advantage to the CH-60 helicopter over the KMAX. Number of pallets per lift is slightly improved by using the CH-60, and mean weight per lift is increased by 4.55 percent.

Appendix H shows the raw data and Appendix I shows the ANOVA analysis for each of the six statistical parameters. Again, the results show that the single engine KMAX uses much less fuel than the dual engine CH-60 helicopter.

However, the advantage by the CH-60 over the KMAX in number of pallets per lift and weight per lift is statistically significant at the 95% level.

D. COMPARISONS BETWEEN MIXED GROUPS OF HELICOPTERS

In the next set of vertical replenishment simulations, a mixture of two different helicopters was combined for analysis. Since the CH-46E is nearly certain to find its way into the Navy's helicopter combat support community in the vertical replenishment role, it was combined with the proposed CH-60 in one set of simulation runs, and with the KMAX helicopter in the other set of simulations. A mixture of CH-60 and KMAX helicopters was not simulated.

1. CH-46E and CH-60

In each two helicopter simulation, one aircraft serviced all ships in the formation while the other serviced all ships except the aircraft carrier. The first question of interest was whether there was a statistically significant difference between assigning the CVN to the CH-46E or the CH-60 helicopter.

Table 7 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for one CH-46E and one CH-60 helicopter, with each assigned to service the CVN.

Elapsed Time	Mean	Std Dev	Conf Interval
CH-46E works CVN	149.45	9.57	6.85
CH-60 works CVN	148.64	4.45	3.18
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	5,929.33	400.40	286.56
CH-60 works CVN	5,920.98	191.85	137.31
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	348.63	49.03	35.09
CH-60 works CVN	338.40	43.03	30.80
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	402.82	391.60	280.26
CH-60 works CVN	388.16	123.97	88.73
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	2.11	0.17	0.11
CH-60 works CVN	2.19	0.17	0.13
Weight/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	4,020.45	278.40	199.25
CH-60 works CVN	4,187.03	354.33	253.59

Table 7. Summary Data for CH-46E and CH-60 Team.

These results show a slight performance improvement by using the CH-60 to service the aircraft carrier. Appendix J shows the raw data and Appendix K shows the ANOVA analysis for each of the six statistical parameters. The ANOVA results show equivalent performance in every parameter except weight per lift where the CH-60 showed a statistically significant improvement. Therefore, for

comparison against the CH-46E and KMAX simulation, the CH-60 would be assigned to service the CVN.

2. CH-46E and KMAX

A similar analysis was completed with the CH-46E and KMAX simulation, this time to determine whether there was a statistically significant difference between assigning the CVN to the CH-46E or the KMAX helicopter.

Table 8 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for one CH-46E and one KMAX helicopter, with each assigned to service the CVN.

Elapsed Time	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	150.07	6.43	4.60
KMAX works CVN	147.16	3.93	2.81
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	4,160.26	173.14	123.91
KMAX works CVN	4,040.49	187.86	134.45
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	363.20	60.49	43.30
KMAX works CVN	344.47	31.26	22.37
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	374.52	157.67	112.84
KMAX works CVN	363.60	106.08	75.92
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-46E works CVN	2.09	0.17	0.12
KMAX works CVN	2.25	0.17	0.12

Weight/Lift	Mean	Std Dev	Conf Interval
CH-46E works CVN	4,002.62	322.10	230.52
KMAX works CVN	4,310.19	341.55	244.44

Table 8. Summary Data for CH-46E and KMAX Team.

These results indicate a modest performance improvement by using the KMAX to service the aircraft carrier. Appendix L shows the raw data and Appendix M shows the ANOVA analysis for each of the six statistical parameters. The ANOVA results shows that using the KMAX to service the CVN takes less time, delivers more pallets per lift, and lifts a greater weight of pallets each trip. Therefore, for comparison against the CH-46E and CH-60 simulation, the KMAX would be assigned to service the CVN.

3. CH-46E and CH-60 versus CH-46E and KMAX

The final analysis of vertical replenishment simulation data compares the mixed CH-46E and CH-60 performance results against the mixed CH-46E and KMAX team. Given that the CH-46E helicopter is used in future vertical replenishment missions, is there a statistically significant advantage to combining it with the CH-60 or the KMAX helicopter?

Table 9 provides a comparison of the mean, standard deviation and 95% confidence interval data resulting from the vertical replenishment simulations for the CH-46E and

CH-60 team versus the CH-46E and KMAX team, with either the CH-60 or the KMAX assigned to service the CVN.

Elapsed Time	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	148.64	4.45	3.18
KMAX works CVN	147.16	3.93	2.81
Fuel Used	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	5,920.98	191.85	137.31
KMAX works CVN	4,040.49	187.86	134.45
Number of Trips	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	338.40	43.03	30.80
KMAX works CVN	344.47	31.26	22.37
Nautical Miles	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	388.16	123.97	88.73
KMAX works CVN	363.60	106.08	75.92
Pallets/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	2.19	0.17	0.13
KMAX works CVN	2.25	0.17	0.12
Weight/Lift	**Mean**	**Std Dev**	**Conf Interval**
CH-60 works CVN	4,187.03	354.33	253.59
KMAX works CVN	4,310.19	341.55	244.44

Table 9. Summary Data for CH-46E & CH-60 vs CH-46E & KMAX.

These results indicate an equivalent performance whether using the CH-60 or the KMAX in combination with the CH-46E. Appendix N shows the raw data and Appendix O shows the ANOVA analysis for each of the six statistical parameters. The ANOVA results confirm that, apart from fuel consumed, using the CH-60 or the KMAX in combination with

the CH-46E yields no statistically significant improvement in the vertical replenishment operation simulated.

V. SIMULATION CONCLUSIONS

The goal of this simulation project was to evaluate the performance characteristics of the CH-46E, the CH-60 and the KMAX helicopters in the vertical replenishment mission of the Navy's helicopter combat support community. Although vertical replenishment is only one of several missions critical to the success of the Navy's logistics support effort, it is a very significant part. Since the KMAX aerial truck is restricted to external cargo delivery only, this project only compared the three helicopters in this mission area.

Tables 10 through 15 list the simulation results for all combinations of the three helicopters analyzed.

Elapsed Time *Aircraft*	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	254.933	2.713	1.941
Two CH-46E (Lo Fuel)	148.538	4.295	3.073
Two CH-60	**144.221**	4.986	3.568
Two KMAX	**144.224**	**6.772**	**4.846**
46&60 (46 works CVN)	149.453	9.566	6.846
46&60 (60 works CVN)	148.640	4.446	3.181
46&KM (46 works CVN)	150.070	6.430	4.602
46&KM (KM works CVN)	147.163	3.929	2.812

Table 10. Elapsed Time for all Helicopter Combinations.

Fuel Consumed			
Aircraft	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	10191.283	106.306	76.082
Two CH-46E (Lo Fuel)	5864.138	198.830	142.300
Two CH-60	5748.704	205.401	147.003
Two KMAX	**2285.450**	71.917	51.470
46&60 (46 works CVN)	5929.326	400.403	286.564
46&60 (60 works CVN)	5920.976	191.855	137.308
46&KM (46 works CVN)	4160.256	173.140	123.914
46&KM (KM works CVN)	4040.493	187.865	134.452

Table 11. Fuel Consumed for all Helicopter Combinations.

Number of Trips			
Aircraft	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	378.666	18.127	12.973
Two CH-46E (Lo Fuel)	354.433	37.444	26.798
Two CH-60	**288.866**	**41.372**	**29.609**
Two KMAX	**282.200**	35.694	25.545
46&60 (46 works CVN)	348.633	49.029	35.089
46&60 (60 works CVN)	338.400	43.030	30.795
46&KM (46 works CVN)	363.200	60.494	43.295
46&KM (KM works CVN)	344.466	31.258	22.371

Table 12. Number of Trips for all Helicopter Combinations.

Nautical Miles			
Aircraft	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	292.345	45.870	32.829
Two CH-46E (Lo Fuel)	328.481	115.776	82.859
Two CH-60	**323.556**	**119.894**	**85.806**
Two KMAX	**319.648**	236.032	168.925
46&60 (46 works CVN)	402.824	391.600	280.264
46&60 (60 works CVN)	388.162	123.974	88.727
46&KM (46 works CVN)	374.521	157.668	112.841
46&KM (KM works CVN)	363.600	106.079	75.919

Table 13. Nautical Miles for all Helicopter Combinations.

Pallets per Lift *Aircraft*	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	1.460	0.071	0.052
Two CH-46E (Lo Fuel)	2.051	0.158	0.113
Two CH-60	**2.470**	0.192	0.137
Two KMAX	2.353	0.155	0.111
46&60 (46 works CVN)	2.105	0.158	0.113
46&60 (60 works CVN)	2.189	0.173	0.125
46&KM (46 works CVN)	2.090	0.170	0.122
46&KM (KM works CVN)	2.254	0.167	0.121

Table 14. Pallets per Lift for all Helicopter Combinations.

Weight per Lift *Aircraft*	*Mean*	*Std Dev*	*CI*
Two CH-46E (Hi Fuel)	2780.648	130.016	93.051
Two CH-46E (Lo Fuel)	3917.862	275.273	197.010
Two CH-60	**4712.488**	356.493	255.138
Two KMAX	4507.065	283.269	202.733
46&60 (46 works CVN)	4020.445	278.400	199.248
46&60 (60 works CVN)	4187.028	354.325	253.587
46&KM (46 works CVN)	4002.622	322.100	230.524
46&KM (KM works CVN)	4310.189	341.549	244.443

Table 15. Weight per Lift for all Helicopter Combinations.

These results indicate that the dual KMAX helicopters use dramatically less fuel than any other dual or mixed aircraft combination. This results follows logically since the KMAX helicopter operates on one turboshaft engine, as opposed to the twin turboshaft configuration of both the CH-46E and the CH-60 helicopters.

For elapsed time, number of trips between ships, and total nautical miles traveled, the dual CH-60 and KMAX helicopter teams look virtually identical. However, the key performance parameters of number of pallets per lift and

weight of pallets per lift give a statistically significant edge to the CH-60 versus the KMAX helicopter. The improvement by the CH-60 over the KMAX is approximately 4% in both parameters.

Statistical analysis of the simulation data (using the analysis of variance techniques) confirms that the CH-60 helicopter possesses higher performance characteristics in the vertical replenishment mission over either the CH-46E or the KMAX helicopters. Again, when comparing number of pallets lifted or mean weight per lift, the CH-60 proved to be a better performer.

The narrow focus of this project on the performance of logistics support helicopters strictly in the vertical replenishment role resulted directly from the limited utility of the KMAX aerial truck. If we take a broader look at all combat logistics missions likely to be assigned to the CH-46D's replacement aircraft, looking from a qualitative instead of a quantitative perspective, the CH-60 helicopter appears to have an even stronger performance advantage. With its internal cargo capacity, the CH-60 will be equipped to carry two pallets of cargo, up to 15 passengers, or a mixture of mail and loose internal cargo. KMAX does not have any internal passenger, mail or cargo transportation capabilities.

From a safely of flight point of view, the ability of the CH-60 to use a coordinated team of pilots and aircrewmen enhances its versatility and dependability in an assortment of missions. Placing both a pilot and copilot in the CH-60 cockpit gives the pilot in command both visual and verbal backup in all phases of flight. During vertical replenishment operations, the aircrewmen working in the aft cabin give the pilot in command an additional set of eyes and ears. The information aircrewmen provide is especially critical during the cargo pickup and drop phases of the VERTREP pattern when the helicopter is closest to the ship's flight deck. For delivery of internal passengers, mail and cargo, the aircrewmen play a vital role in ensuring safety of each passenger, security for important repair parts and equipment, and reliable delivery of standard and registered mail. Kaman Aerospace Corporation proposes to equip KMAX with a buoyant cargo basket for external lift of mail, an idea impractical in the often harsh environmental conditions typical of vertical replenishment at sea. In fact, many of the Navy's helicopter combat support squadrons maintain as standard operating procedure a prohibition on the external transportation of mail.

Logistics requirements at sea are fluid and often require short notice changes in plans. A scheduled five hour

replenishment can easily extend to twice that length, as additional requirements surface and ships delay scheduled receipt of cargo. The typical Navy logistics helicopter detachment provides six pilots and aircrewmen to conduct flight operations with two helicopters. The Kaman proposal to field a two helicopter detachment with only two pilots may severely strain the ability of the pilots to sustain continuous logistics operations over a period of days or even weeks at sea.

There are many other qualitative factors which can be considered when weighing the relative advantages of the CH-60 versus the KMAX as the follow-on helicopter to augment and/or replace both the CH-46D and the CH-46E aircraft. Senior planners must weigh them carefully against the budgetary constraints likely during the next twenty years. This project does give a useful quantitative basis for demonstrating that, in the vertical replenishment role, the CH-60 performs as well if not a bit better than the KMAX helicopter. This quantitative analysis should play an important role in the overall decision making process within the Navy's planning, programming and budgetary process. The ability of the Navy's combat helicopter support community to meet the future logistics support requirements of the fleet

into the twenty-first century depends on the ultimate decisions made.

APPENDIX A: HELICOPTER DATA

CH-46E (High Fuel)	
Operating Weight	18,020 pounds
Max Gross Weight	24,300 pounds
Max Number of Pallets	Four
Max Fuel Capacity	4,488 pounds JP-5
Min Fuel Capacity	400 pounds JP-5
Fuel Consumption Rate	20 pounds per minute JP-5
VERTREP speed	0.67 nautical miles per minute
External Hook Weight Capacity	10,000 pounds

CH-46E (Low Fuel)	
Operating Weight	18,020 pounds
Max Gross Weight	24,300 pounds
Max Number of Pallets	Four
Max Fuel Capacity	2,421 pounds JP-5
Min Fuel Capacity	400 pounds JP-5
Fuel Consumption Rate	20 pounds per minute JP-5
VERTREP speed	0.67 nautical miles per minute
External Hook Weight Capacity	10,000 pounds

CH-60	
Operating Weight	13,662 pounds
Max Gross Weight	22,000 pounds
Max Number of Pallets	Four
Max Fuel Capacity	2,446 pounds JP-5
Min Fuel Capacity	400 pounds JP-5
Fuel Consumption Rate	20 pounds per minute JP-5
VERTREP speed	0.67 nautical miles per minute
External Hook Weight Capacity	6,000 pounds

KMAX	
Operating Weight	5,000 pounds
Max Gross Weight	11,500 pounds
Max Number of Pallets	Four
Max Fuel Capacity	1,000 pounds JP-5
Min Fuel Capacity	160 pounds JP-5
Fuel Consumption Rate	8 pounds per minute JP-5
VERTREP speed	0.67 nautical miles per minute
External Hook Weight Capacity	6,000 pounds

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APPENDIX B: SIMULATION DATA FOR CH-46E (HIGH & LOW FUEL)

Rep	Elapsed Time		Fuel Burned		Number of Trips	
	CH46E HiFuel	CH46E LoFuel	CH46E HiFuel	CH46E LoFuel	CH46E HiFuel	CH46E LoFuel
1	255.7069	157.9222	10224.1201	6298.0448	373	414
2	248.5118	148.2862	9936.3649	5917.7275	356	325
3	252.5263	153.1481	10100.3758	6124.7635	366	412
4	257.9996	149.7255	10312.2931	5984.8561	379	362
5	254.9733	142.1485	10195.3995	5455.9256	393	316
6	257.1426	149.9610	10284.7299	5965.2034	391	348
7	254.6720	146.2100	10179.3952	5669.6993	370	328
8	253.1946	152.6806	10124.6825	6103.4304	358	374
9	256.4395	145.3822	10256.9398	5800.5973	396	283
10	255.8178	146.9886	10226.2644	5865.0800	389	349
11	253.5894	148.1173	10140.3676	5691.5978	385	365
12	256.7270	145.4845	10261.1374	5805.2794	383	327
13	252.4437	149.9115	10093.7879	5971.5630	380	331
14	260.2674	156.3654	10396.5048	6252.5697	408	392
15	251.8189	154.4716	10071.2734	6175.5401	382	385
16	256.9111	146.5260	10262.3760	5842.9590	390	372
17	255.4152	148.7124	10211.4330	5604.5682	407	366
18	256.8149	147.2285	10257.4655	5865.2018	370	314
19	253.0253	143.9880	10118.2016	5747.5302	380	326
20	252.3596	141.9381	10086.1592	5661.0800	358	319
21	254.9386	147.6155	10187.9552	5787.6786	376	327
22	255.1559	156.6168	10202.5398	5827.4586	380	431
23	258.1133	149.7339	10315.4764	5987.8323	423	378
24	249.6596	146.8788	9981.9154	5759.7720	365	338
25	253.3095	141.1104	10125.9858	5609.7296	338	308
26	256.7633	150.5069	10261.4095	5798.5761	377	373
27	251.8014	147.3074	10070.1456	5890.6448	349	335
28	259.2984	143.4358	10361.2802	5721.5766	396	339
29	255.4446	151.2447	10214.8219	6039.2874	377	436
30	257.1777	146.4953	10277.6900	5698.3834	365	360

Rep	NMiles		Pallets Per Lift		Weight Per Lift	
	CH46E HiFuel	CH46E LoFuel	CH46E HiFuel	CH46E LoFuel	CH46E HiFuel	CH46E LoFuel
1	286.9751	606.8602	1.5245	1.9818	2916.2857	3791.1714
2	248.4831	305.3497	1.5571	2.3478	2922.7865	4391.6701
3	240.1903	400.4592	1.5282	1.9727	2913.9489	3896.0257
4	292.7361	419.8624	1.3711	2.1600	2600.4009	4061.2291
5	307.4872	219.1053	1.4932	2.1287	2830.5452	3954.0956
6	369.6099	298.9154	1.3540	1.9907	2586.8010	3873.9579
7	257.8106	244.2059	1.3133	2.0377	2510.5758	3856.2723
8	218.2944	466.9447	1.4662	2.0187	2828.9999	3764.8957
9	357.5756	179.2809	1.5461	2.0000	2979.7625	3768.1818
10	355.2489	275.5418	1.4065	2.0769	2661.0371	4070.6714
11	310.7503	270.4435	1.4437	2.0472	2768.8882	3955.4678
12	267.3863	244.9483	1.4248	1.9286	2742.7055	3588.1465
13	251.1556	390.9136	1.3711	2.0472	2670.2530	3878.6371
14	353.7372	639.2948	1.4830	2.3478	2777.1978	4477.8683
15	252.5291	401.2745	1.3540	2.1700	2603.4801	4138.6712
16	273.3978	295.6681	1.5245	2.0769	2867.5542	3962.3298
17	290.5772	276.1653	1.4533	1.7419	2844.8805	3356.7189
18	277.0511	243.1655	1.4830	1.8305	2874.3829	3568.3261
19	275.4033	239.2605	1.5571	2.1078	2881.9752	4088.4874
20	238.6427	207.0893	1.4065	1.8783	2672.7966	3681.5670
21	389.5067	241.6473	1.4342	1.7008	2693.4834	3364.0422
22	331.9473	501.8954	1.4342	2.0962	2739.8828	3944.2611
23	347.3066	337.3577	1.4437	2.1818	2817.5732	4225.7744
24	256.6458	254.9320	1.5500	2.1176	2895.6063	4092.8820
25	235.3572	202.2789	1.3822	1.9725	2576.1556	3729.4837
26	355.2611	397.7887	1.4830	2.2268	2784.4213	4180.6018
27	267.5794	292.0859	1.5245	1.9286	2871.2299	3667.8207
28	289.2266	259.1455	1.5912	2.3478	3015.7675	4392.8750
29	274.5942	439.9091	1.3974	1.9286	2697.4616	3772.8484
30	297.9076	302.6521	1.5245	2.1400	2872.6178	4040.9019

APPENDIX C: ANOVA TABLES FOR CH-46E (HIGH & LOW FUEL)

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	7,648.019	254.834	7.362
CH-46E LoFuel	30	4,456.142	148.538	18.445
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		169,801.374	1	169,801.374
Within Groups		748.392	58	12.903
Total		170,549.765	59	
F		***P-value***		***F-crit***
13,159.525		***4.41911E-70***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	305,738.491	10,191.283	11,301.011
CH-46E LoFuel	30	175,924.156	5,864.139	39,533.377
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		280,862,693	1	280,862,693
Within Groups		1,474,197	58	25,417
Total		282,336,890	59	
F		***P-value***		***F-crit***
11,050.106		***6.8439E-68***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	11,360	378.667	328.575
CH-46E LoFuel	30	10,633	354.433	1,402.047
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		8,808.817	1	8,808.817
Within Groups		50,188.033	58	865.311
Total		58,996.850	59	
F		***P-value***		***F-crit***
10.180		***0.002***		***4.007***

ANOVA: SINGLE FACTOR				
NAUTICAL MILES TRAVELED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	8,770.374	292.346	2,104.097
CH-46E LoFuel	30	9,854.442	328.481	13,404.128
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		19,586.694	1	19,586.694
Within Groups		449,738.526	58	7,754.113
Total		469,325.219	59	
F		***P-value***		***F-crit***
2.526		***0.117***		***4.007***

ANOVA: SINGLE FACTOR				
PALLETS PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	43.826	1.461	0.005
CH-46E LoFuel	30	61.532	2.051	0.025
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		5.225	1	5.225
Within Groups		0.884	58	0.015
Total		6.109	59	
F		***P-value***		***F-crit***
342.900		***5.039E-26***		***4.007***

ANOVA: SINGLE FACTOR				
WEIGHT PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E HiFuel	30	83,419.457	2,780.649	16,904.113
CH-46E LoFuel	30	117,535.882	3,917.863	75,774.970
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		19,398,841	1	19,398,841
Within Groups		2,687,693	58	46,339
Total		22,086,534	59	
F		***P-value***		***F-crit***
418.624		***3.295E-28***		***4.007***

APPENDIX D: SIMULATION DATA FOR CH-46E AND CH-60

	Elapsed Time		Fuel Used		Trips	
Rep	CH46E	CH60	CH46E	CH60	CH46E	CH60
1	157.9222	139.5594	6298.0448	5575.5988	414	289
2	148.2862	145.3459	5917.7275	5805.3056	325	338
3	153.1481	141.7042	6124.7635	5648.4991	412	262
4	149.7255	154.8965	5984.8561	6195.7840	362	280
5	142.1485	145.7649	5455.9256	5826.5401	316	346
6	149.9610	148.4206	5965.2034	5772.0328	348	294
7	146.2100	142.6348	5669.6993	5673.0309	328	289
8	152.6806	140.3207	6103.4304	5597.1361	374	238
9	145.3822	145.8437	5800.5973	5829.2138	283	310
10	146.9886	142.6700	5865.0800	5705.2183	349	261
11	148.1173	142.4589	5691.5978	5697.2952	365	268
12	145.4845	141.0914	5805.2794	5482.5798	327	267
13	149.9115	154.7583	5971.5630	6190.1619	331	304
14	156.3654	139.7336	6252.5697	5587.2735	392	266
15	154.4716	153.6465	6175.5401	6137.7052	385	421
16	146.5260	141.7870	5842.9590	5670.0126	372	250
17	148.7124	143.0195	5604.5682	5698.2246	366	279
18	147.2285	147.0662	5865.2018	5867.7232	314	329
19	143.9880	150.0945	5747.5302	5993.1374	326	321
20	141.9381	141.1106	5661.0800	5635.1924	319	298
21	147.6155	139.0875	5787.6786	5556.8947	327	254
22	156.6168	142.0670	5827.4586	5674.6558	431	255
23	149.7339	146.6072	5987.8323	5856.7987	378	347
24	146.8788	142.0684	5759.7720	5661.8976	338	294
25	141.1104	142.7072	5609.7296	5700.3467	308	257
26	150.5069	142.8714	5798.5761	5713.0136	373	266
27	147.3074	138.5928	5890.6448	5511.3196	335	268
28	143.4358	139.1056	5721.5766	5547.2013	339	214
29	151.2447	153.9891	6039.2874	6158.4936	436	334
30	146.4953	137.6247	5698.3834	5492.8364	360	267

	Nautical Miles		Pallets/Lift		Weight/Lift	
Rep	CH46E	CH60	CH46E	CH60	CH46E	CH60
1	606.8602	296.3608	1.9818	2.7342	3791.1714	5256.0614
2	305.3497	327.9019	2.3478	2.1068	4391.6701	4098.6627
3	400.4592	268.0046	1.9727	2.4270	3896.0257	4571.1648
4	419.8624	500.7995	2.1600	2.4773	4061.2291	4649.8296
5	219.1053	352.9750	2.1287	2.4828	3954.0956	4840.1357
6	298.9154	468.8916	1.9907	2.3736	3873.9579	4433.5407
7	244.2059	281.6099	2.0377	2.4828	3856.2723	4872.2786
8	466.9447	202.1455	2.0187	2.2500	3764.8957	4276.7261
9	179.2809	343.5941	2.0000	2.4270	3768.1818	4547.2661
10	275.5418	237.8748	2.0769	2.4659	4070.6714	4695.9520
11	270.4435	280.6685	2.0472	2.3478	3955.4678	4520.9604
12	244.9483	293.5488	1.9286	2.4828	3588.1465	4670.1197
13	390.9136	414.3709	2.0472	2.4494	3878.6371	4699.9268
14	639.2948	255.9431	2.3478	2.2268	4477.8683	4222.7888
15	401.2745	794.4656	2.1700	2.5057	4138.6712	4951.3154
16	295.6681	188.8496	2.0769	2.1176	3962.3298	4078.4283
17	276.1653	285.6418	1.7419	2.7000	3356.7189	5186.8123
18	243.1655	423.2393	1.8305	2.4494	3568.3261	4569.6048
19	239.2605	382.5791	2.1078	2.4773	4088.4874	4679.8874
20	207.0893	335.0479	1.8783	2.8421	3681.5670	5452.4479
21	241.6473	284.8247	1.7008	2.9589	3364.0422	5512.8828
22	501.8954	277.2615	2.0962	2.4545	3944.2611	4734.2847
23	337.3577	418.2495	2.1818	2.5529	4225.7744	4926.1909
24	254.9320	300.5231	2.1176	2.1818	4092.8820	4229.3908
25	202.2789	214.5992	1.9725	2.4659	3729.4837	4598.7458
26	397.7887	274.9790	2.2268	2.5714	4180.6018	4890.7157
27	292.0859	248.1597	1.9286	2.6220	3667.8207	4949.5383
28	259.1455	168.0280	2.3478	2.6667	4392.8750	4971.3468
29	439.9091	346.5461	1.9286	2.3404	3772.8484	4535.9632
30	302.6521	239.0177	2.1400	2.4828	4040.9019	4751.6849

APPENDIX E: ANOVA TABLES FOR CH-46E AND CH-60

ANOVA: SINGLE FACTOR
ELAPSED TIME

SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	4,456.142	148.538	18.445
CH-60	30	4,326.648	144.222	24.856

ANOVA			
Source of Variation	*SS*	*df*	*MS*
Between Groups	279.475	1	279.475
Within Groups	1,225.727	58	21.650
Total	1,535.202	59	

F	***P-value***	***F-crit***
12.908	***0.001***	***4.007***

ANOVA: SINGLE FACTOR
FUEL CONSUMED

SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	175,924.156	5,864.139	39,533.377
CH-60	30	172,461.123	5,748.704	42,189.391

ANOVA			
Source of Variation	*SS*	*df*	*MS*
Between Groups	199,876	1	199,876
Within Groups	2,369,960	58	40,861
Total	2,569,836	59	

F	***P-value***	***F-crit***
4.892	***0.031***	***4.007***

ANOVA: SINGLE FACTOR
NUMBER OF TRIPS

SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	10,633	354.433	1,402.047
CH-60	30	8,666	288.867	1,711.637

ANOVA			
Source of Variation	*SS*	*df*	*MS*
Between Groups	64,484.817	1	64,484.817
Within Groups	90,296.833	58	1,556.842
Total	154,781.650	59	

F	***P-value***	***F-crit***
41.420	***2.58E-08***	***4.007***

ANOVA: SINGLE FACTOR				
NAUTICAL MILES TRAVELED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	9,854.442	328.481	13,404.128
CH-60	30	9,706.701	323.557	14,374.534
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		363.789	1	363.789
Within Groups		805,581.190	58	13,889.331
Total		805,944.980	59	
F		***P-value***		***F-crit***
0.026		***0.872***		***4.007***

ANOVA: SINGLE FACTOR				
PALLETS PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	61.532	2.051	0.025
CH-60	30	74.124	2.471	0.037
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		2.642	1	2.642
Within Groups		1.803	58	0.031
Total		4.445	59	
F		***P-value***		***F-crit***
84.997		***5.774E-13***		***4.007***

ANOVA: SINGLE FACTOR				
WEIGHT PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	117,535.882	3,917.863	75,774.970
CH-60	30	141,374.653	4,712.488	127,087.025
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		9,471,450	1	9,471,450
Within Groups		5,882,997	58	101,430
Total		15,354,447	59	
F		***P-value***		***F-crit***
93.378		***1.087E-13***		***4.007***

APPENDIX F: SIMULATION DATA FOR CH-46E AND KMAX

	Elapsed Time		Fuel Burned		Trips	
Rep	CH46E	KMAX	CH46E	KMAX	CH46E	KMAX
1	157.9222	139.1260	6298.0448	2204.8597	414	254
2	148.2862	143.9141	5917.7275	2241.2202	325	286
3	153.1481	139.7068	6124.7635	2233.1382	412	221
4	149.7255	142.4618	5984.8561	2270.1877	362	282
5	142.1485	141.5704	5455.9256	2260.9629	316	241
6	149.9610	141.5505	5965.2034	2259.8723	348	262
7	146.2100	139.2678	5669.6993	2228.0691	328	281
8	152.6806	174.2968	6103.4304	2501.3445	374	376
9	145.3822	147.1083	5800.5973	2270.1649	283	291
10	146.9886	141.3637	5865.0800	2260.3153	349	296
11	148.1173	140.5711	5691.5978	2245.8099	365	254
12	145.4845	140.6896	5805.2794	2183.3678	327	271
13	149.9115	139.4655	5971.5630	2224.0539	331	261
14	156.3654	152.7159	6252.5697	2443.3506	392	362
15	154.4716	147.1513	6175.5401	2352.6218	385	331
16	146.5260	149.7453	5842.9590	2325.0082	372	257
17	148.7124	142.5395	5604.5682	2276.7547	366	271
18	147.2285	139.2901	5865.2018	2227.8734	314	274
19	143.9880	143.1239	5747.5302	2283.0905	326	245
20	141.9381	144.3141	5661.0800	2307.4444	319	282
21	147.6155	139.2756	5787.6786	2227.1422	327	253
22	156.6168	142.7833	5827.4586	2284.5279	431	290
23	149.7339	142.0575	5987.8323	2270.3063	378	244
24	146.8788	139.6141	5759.7720	2223.0250	338	291
25	141.1104	144.7783	5609.7296	2315.8817	308	301
26	150.5069	140.9151	5798.5761	2252.6404	373	271
27	147.3074	152.1349	5890.6448	2432.4965	335	311
28	143.4358	145.2211	5721.5766	2322.5895	339	335
29	151.2447	146.4639	6039.2874	2343.0479	436	320
30	146.4953	143.5329	5698.3834	2292.3367	360	252

	NMiles		Pallets Per Lift		Weight Per Lift	
Rep	CH46E	KMAX	CH46E	KMAX	CH46E	KMAX
1	606.8602	228.1403	1.9818	2.2500	3791.1714	4325.3005
2	305.3497	253.9850	2.3478	2.2737	4391.6701	4258.0669
3	400.4592	225.5567	1.9727	2.6667	3896.0257	4922.6470
4	419.8624	217.9996	2.1600	2.6024	4061.2291	5116.3469
5	219.1053	187.6807	2.1287	2.1176	3954.0956	4073.2210
6	298.9154	194.8879	1.9907	2.5412	3873.9579	4736.2049
7	244.2059	277.3829	2.0377	2.4828	3856.2723	4683.7207
8	466.9447	1474.8022	2.0187	2.2577	3764.8957	4307.9401
9	179.2809	417.4307	2.0000	2.3956	3768.1818	4508.0992
10	275.5418	249.6560	2.0769	2.0971	4070.6714	4031.9150
11	270.4435	249.8320	2.0472	2.4828	3955.4678	4753.9596
12	244.9483	211.9581	1.9286	2.3626	3588.1465	4665.6657
13	390.9136	221.4167	2.0472	2.2979	3878.6371	4401.2628
14	639.2948	491.5692	2.3478	2.2474	4477.8683	4444.1676
15	401.2745	358.1427	2.1700	2.2979	4138.6712	4466.7658
16	295.6681	499.7966	2.0769	2.6667	3962.3298	5162.4214
17	276.1653	353.4708	1.7419	2.4432	3356.7189	4688.9480
18	243.1655	220.8801	1.8305	2.3736	3568.3261	4524.5631
19	239.2605	203.0916	2.1078	2.1818	4088.4874	4305.1207
20	207.0893	262.5974	1.8783	2.2500	3681.5670	4254.7470
21	241.6473	206.6739	1.7008	2.2268	3364.0422	4320.2194
22	501.8954	267.9520	2.0962	2.3736	3944.2611	4542.3097
23	337.3577	164.7926	2.1818	2.3736	4225.7744	4537.2524
24	254.9320	252.4626	2.1176	2.4828	4092.8820	4693.3650
25	202.2789	340.4852	1.9725	2.1600	3729.4837	4178.6715
26	397.7887	248.8364	2.2268	2.4432	4180.6018	4682.6227
27	292.0859	332.4868	1.9286	2.3587	3667.8207	4410.6351
28	259.1455	368.2658	2.3478	2.4828	4392.8750	4747.4628
29	439.9091	426.8305	1.9286	2.3226	3772.8484	4398.4940
30	302.6521	180.3981	2.1400	2.0971	4040.9019	4069.8533

APPENDIX G: ANOVA TABLES FOR CH-46E AND KMAX

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	4,456.142	148.538	18.445
KMAX	30	4,326.749	144.225	45.866
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		279.039	1	279.039
Within Groups		1,864.994	58	32.155
Total		2,144.033	59	
F		***P-value***		***F-crit***
8.678		***0.005***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	175,924.156	5,864.139	39,533.377
KMAX	30	68,563.504	2,285.450	5,172.077
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		192,105,162	1	192,105,162
Within Groups		1,296,458	58	22,352
Total		193,401,620	59	
F		***P-value***		***F-crit***
8,594.261		***9.603E-65***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E	30	10,633	354.433	1,402.047
KMAX	30	8,466	282.200	1,274.028
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		78,264.817	1	78,264.817
Within Groups		77,606.167	58	1,338.037
Total		155,870.983	59	
F		***P-value***		***F-crit***
58.492		***2.387E-10***		***4.007***

ANOVA: SINGLE FACTOR					
NAUTICAL MILES TRAVELED					
SUMMARY					
GROUPS	*COUNT*	*SUM*		*AVERAGE*	*VARIANCE*
CH-46E	30	9,854.442		328.481	13,404.128
KMAX	30	9,589.461		319.649	55,710.920
ANOVA					
Source of Variation		*SS*	*df*		*MS*
Between Groups		1,170	1		1,170
Within Groups		2,004,336	58		34,557
Total		2,005,506	59		
F		***P-value***		***F-crit***	
0.0339		***0.8546***		***4.007***	

ANOVA: SINGLE FACTOR					
PALLETS PER LIFT					
SUMMARY					
GROUPS	*COUNT*	*SUM*		*AVERAGE*	*VARIANCE*
CH-46E	30	61.532		2.051	0.025
KMAX	30	70.610		2.354	0.024
ANOVA					
Source of Variation		*SS*	*df*		*MS*
Between Groups		1.373	1		1.373
Within Groups		1.434	58		0.025
Total		2.808	59		
F		***P-value***		***F-crit***	
55.536		***5.092E-10***		***4.007***	

ANOVA: SINGLE FACTOR					
WEIGHT PER LIFT					
SUMMARY					
GROUPS	*COUNT*	*SUM*		*AVERAGE*	*VARIANCE*
CH-46E	30	117,535.882		3,917.863	75,774.970
KMAX	30	135,211.970		4,507.066	80,241.418
ANOVA					
Source of Variation		*SS*	*df*		*MS*
Between Groups		5,207,401	1		5,207,401
Within Groups		4,524,475	58		78,008
Total		9,731,876	59		
F		***P-value***		***F-crit***	
66.755		***3.176E-11***		***4.007***	

APPENDIX H: SIMULATION DATA FOR CH-60 AND KMAX

Rep	Elapsed Time		Fuel Burned		Number of Trips	
	CH60	KMAX	CH60	KMAX	CH60	KMAX
1	139.5594	139.1260	5575.5988	2204.8597	289	254
2	145.3459	143.9141	5805.3056	2241.2202	338	286
3	141.7042	139.7068	5648.4991	2233.1382	262	221
4	154.8965	142.4618	6195.7840	2270.1877	280	282
5	145.7649	141.5704	5826.5401	2260.9629	346	241
6	148.4206	141.5505	5772.0328	2259.8723	294	262
7	142.6348	139.2678	5673.0309	2228.0691	289	281
8	140.3207	174.2968	5597.1361	2501.3445	238	376
9	145.8437	147.1083	5829.2138	2270.1649	310	291
10	142.6700	141.3637	5705.2183	2260.3153	261	296
11	142.4589	140.5711	5697.2952	2245.8099	268	254
12	141.0914	140.6896	5482.5798	2183.3678	267	271
13	154.7583	139.4655	6190.1619	2224.0539	304	261
14	139.7336	152.7159	5587.2735	2443.3506	266	362
15	153.6465	147.1513	6137.7052	2352.6218	421	331
16	141.7870	149.7453	5670.0126	2325.0082	250	257
17	143.0195	142.5395	5698.2246	2276.7547	279	271
18	147.0662	139.2901	5867.7232	2227.8734	329	274
19	150.0945	143.1239	5993.1374	2283.0905	321	245
20	141.1106	144.3141	5635.1924	2307.4444	298	282
21	139.0875	139.2756	5556.8947	2227.1422	254	253
22	142.0670	142.7833	5674.6558	2284.5279	255	290
23	146.6072	142.0575	5856.7987	2270.3063	347	244
24	142.0684	139.6141	5661.8976	2223.0250	294	291
25	142.7072	144.7783	5700.3467	2315.8817	257	301
26	142.8714	140.9151	5713.0136	2252.6404	266	271
27	138.5928	152.1349	5511.3196	2432.4965	268	311
28	139.1056	145.2211	5547.2013	2322.5895	214	335
29	153.9891	146.4639	6158.4936	2343.0479	334	320
30	137.6247	143.5329	5492.8364	2292.3367	267	252

Rep	NMiles		Pallets Per Lift		Weight Per Lift	
	CH60	KMAX	CH60	KMAX	CH60	KMAX
1	296.3608	228.1403	2.7342	2.2500	5256.0614	4325.3005
2	327.9019	253.9850	2.1068	2.2737	4098.6627	4258.0669
3	268.0046	225.5567	2.4270	2.6667	4571.1648	4922.6470
4	500.7995	217.9996	2.4773	2.6024	4649.8296	5116.3469
5	352.9750	187.6807	2.4828	2.1176	4840.1357	4073.2210
6	468.8916	194.8879	2.3736	2.5412	4433.5407	4736.2049
7	281.6099	277.3829	2.4828	2.4828	4872.2786	4683.7207
8	202.1455	1474.8022	2.2500	2.2577	4276.7261	4307.9401
9	343.5941	417.4307	2.4270	2.3956	4547.2661	4508.0992
10	237.8748	249.6560	2.4659	2.0971	4695.9520	4031.9150
11	280.6685	249.8320	2.3478	2.4828	4520.9604	4753.9596
12	293.5488	211.9581	2.4828	2.3626	4670.1197	4665.6657
13	414.3709	221.4167	2.4494	2.2979	4699.9268	4401.2628
14	255.9431	491.5692	2.2268	2.2474	4222.7888	4444.1676
15	794.4656	358.1427	2.5057	2.2979	4951.3154	4466.7658
16	188.8496	499.7966	2.1176	2.6667	4078.4283	5162.4214
17	285.6418	353.4708	2.7000	2.4432	5186.8123	4688.9480
18	423.2393	220.8801	2.4494	2.3736	4569.6048	4524.5631
19	382.5791	203.0916	2.4773	2.1818	4679.8874	4305.1207
20	335.0479	262.5974	2.8421	2.2500	5452.4479	4254.7470
21	284.8247	206.6739	2.9589	2.2268	5512.8828	4320.2194
22	277.2615	267.9520	2.4545	2.3736	4734.2847	4542.3097
23	418.2495	164.7926	2.5529	2.3736	4926.1909	4537.2524
24	300.5231	252.4626	2.1818	2.4828	4229.3908	4693.3650
25	214.5992	340.4852	2.4659	2.1600	4598.7458	4178.6715
26	274.9790	248.8364	2.5714	2.4432	4890.7157	4682.6227
27	248.1597	332.4868	2.6220	2.3587	4949.5383	4410.6351
28	168.0280	368.2658	2.6667	2.4828	4971.3468	4747.4628
29	346.5461	426.8305	2.3404	2.3226	4535.9632	4398.4940
30	239.0177	180.3981	2.4828	2.0971	4751.6849	4069.8533

APPENDIX I: ANOVA TABLES FOR CH-60 AND KMAX

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	4,326.648	144.222	24.856
KMAX	30	4,326.749	144.225	45.866
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		0.000	1	0.000
Within Groups		2,050.936	58	35.361
Total		2,050.936	59	
F		***P-value***		***F-crit***
4.807E-6		***0.998***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	172,461.123	5,748.704	42,189.391
KMAX	30	68,563.504	2,285.450	5,172.077
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		179,911,922	1	179,911,922
Within Groups		1,373,482	58	23,680
Total		181,285,404	59	
F		***P-value***		***F-crit***
7,597.396		***3.344E-63***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	8,666	288.867	1,711.637
KMAX	30	8,466	282.200	1,274.028
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		666.667	1	666.667
Within Groups		86,584.267	58	1,492.832
Total		87,250.933	59	
F		***P-value***		***F-crit***
0.447		***0.507***		***4.007***

ANOVA: SINGLE FACTOR				
NAUTICAL MILES TRAVELED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	9,706.701	232.557	14,374.534
KMAX	30	9,589.461	219.649	55,710.920
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		229	1	229.086
Within Groups		2,032,478	58	35,042.727
Total		2,032,707	59	
F		***P-value***		***F-crit***
0.007		***0.936***		***4.007***

ANOVA: SINGLE FACTOR				
PALLETS PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	74.124	2.471	0.037
KMAX	30	70.610	2.354	0.024
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		0.206	1	0.206
Within Groups		1.778	58	0.031
Total		1.984	59	
F		***P-value***		***F-crit***
6.711		***0.012***		***4.007***

ANOVA: SINGLE FACTOR				
WEIGHT PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60	30	141,374.653	4,712.488	127,087.025
KMAX	30	135,211.970	4,507.066	80,241.418
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		632,977	1	632,977
Within Groups		6,012,524	58	103,664
Total		6,645,501	59	
F		***P-value***		***F-crit***
6.106		***0.016***		***4.007***

APPENDIX J: SIMULATION DATA FOR CH-46E AND CH-60 MIXED

(CH-46 SERVICING CVN VERSUS CH-60 SERVICING CVN)

Rep	Elapsed Time		Fuel Burned		Number of Trips	
	46 works CVN	60 works CVN	46 works CVN	60 works CVN	46 works CVN	60 works CVN
1	149.2584	144.8082	5963.5032	5790.2668	365	332
2	150.9752	143.3015	6032.3842	5728.6111	415	317
3	143.8030	149.1310	5728.0859	5848.1525	319	363
4	148.7127	149.0585	5918.9412	5947.0813	334	333
5	146.8991	140.8756	5704.3646	5624.3197	304	259
6	143.6539	147.8666	5625.7676	5912.8065	296	391
7	193.9294	146.3378	7757.1685	5845.5298	478	350
8	144.2597	142.3421	5721.5220	5663.4364	325	290
9	143.0318	146.3445	5714.7176	5850.3489	291	325
10	153.8247	146.6756	6150.1575	5864.8886	353	330
11	153.7048	146.6986	6137.7765	5854.4548	401	346
12	147.1687	158.2639	5875.4558	6326.2793	367	336
13	143.2598	150.1044	5582.2664	5985.6230	290	334
14	145.9156	158.7243	5627.1762	6345.2965	345	410
15	146.9699	148.6716	5852.4959	5943.5558	343	296
16	146.0125	146.0143	5741.4961	5840.5106	323	276
17	144.8262	153.8816	5745.2216	6152.1195	309	310
18	146.0958	149.1139	5819.9555	5960.5199	329	325
19	145.0096	149.6612	5750.8983	5984.4311	349	337
20	151.6244	150.6205	5928.6812	6016.6761	349	411
21	145.5630	154.5528	5808.1759	6081.4335	350	360
22	152.1834	146.0540	6072.7529	5838.6218	384	322
23	143.5737	156.6204	5741.4275	6253.2070	303	470
24	146.0903	151.5893	5799.5589	6060.1837	318	379
25	149.4968	143.2869	5960.0168	5726.8314	345	318
26	147.1647	147.0197	5772.2465	5865.6771	326	307
27	150.8994	149.1707	6033.2212	5947.7421	395	349
28	160.6693	151.5623	6415.9623	6061.3935	442	360
29	140.4945	145.2239	5605.1041	5503.4409	273	314
30	158.5325	145.6450	6293.2936	5805.8526	438	302

Rep	NMiles		Pallets Per Lift		Weight Per Lift	
	46 works CVN	60 works CVN	46 works CVN	60 works CVN	46 works CVN	60 works CVN
1	340.5221	482.5852	2.1818	2.1485	4194.2308	4120.0876
2	430.1770	309.4694	2.1818	2.3478	4164.4499	4361.1653
3	225.2119	363.0041	1.9115	2.2143	3785.7080	4277.1410
4	311.2625	271.5019	1.9459	1.9375	3672.6229	3733.3137
5	253.7671	191.7259	2.0377	2.2737	4012.1956	4388.3633
6	336.0173	433.6103	2.0571	2.1373	3750.6443	3933.2667
7	2394.9589	388.0867	2.0660	2.2041	3897.3631	4235.5580
8	247.0736	326.9319	2.2500	2.5116	4296.1552	4766.7991
9	271.2233	262.4817	2.1078	2.1176	4001.3124	4035.8655
10	450.6496	336.2915	2.3846	2.4270	4536.1990	4701.4697
11	458.5947	304.1949	2.3191	2.0971	4323.4684	4002.0862
12	367.5943	467.9796	2.2604	2.1683	4363.3621	4043.9346
13	196.1886	478.0414	1.8947	2.4270	3706.2011	4682.8521
14	243.5072	503.8380	1.8000	1.8879	3559.4443	3610.4382
15	328.0058	281.2235	2.0769	1.8534	3927.0233	3579.3678
16	228.4761	286.1782	2.0673	2.2041	3890.0333	4059.5578
17	222.7216	338.1444	1.9459	2.1386	3772.8715	4137.3742
18	298.5271	262.3824	2.2737	1.8632	4357.2394	3601.5428
19	307.2283	436.7049	2.1176	2.1919	4079.3518	4103.7929
20	388.5983	521.9478	2.0093	2.1800	3902.8215	4257.1418
21	282.1829	520.5713	1.8305	2.3118	3552.7532	4435.9626
22	435.5795	261.4001	2.0769	2.0472	4148.9715	3780.9685
23	235.5546	782.4706	2.0971	1.9550	3912.9278	3784.8098
24	320.7757	578.2101	2.3226	2.4659	4398.8900	4842.6247
25	286.7976	325.9675	2.2979	2.1818	4398.6652	4229.2865
26	351.5350	277.4500	2.3478	2.3736	4394.1782	4614.9921
27	473.0390	391.5406	2.0865	2.1584	3980.7862	4050.0354
28	640.2922	515.3562	1.9123	2.2500	3617.5378	4316.0194
29	187.5987	382.7837	2.2268	2.3889	4094.1308	4680.4501
30	571.0725	362.8090	2.0762	2.2268	3921.8171	4244.5824

APPENDIX K: ANOVA TABLES FOR CH-46E AND CH-60 MIXED

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	4,483.603	149.453	91.519
CH-60 SERVICES CVN	30	4,459.221	148.641	19.763
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		9.908	1	9.908
Within Groups		3,227.178	58	55.641
Total		3,237.086	59	
F		***P-value***		***F-crit***
0.178		***0.675***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	177,879.795	5,929.327	160,322.402
CH-60 SERVICES CVN	30	177,629.292	5,920.976	36,808.261
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		1,045	1	1,045
Within Groups		5,716,789	58	98,565
Total		5,717,834	59	
F		***P-value***		***F-crit***
0.011		***0.918***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	10,459	348.633	2,403.826
CH-60 SERVICES CVN	30	10,152	338.400	1,851.559
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		1,570.817	1	1,570.817
Within Groups		123,406.167	58	2,127.693
Total		124,976.983	59	
F		***P-value***		***F-crit***
0.738		***0.394***		***4.007***

ANOVA: SINGLE FACTOR				
NAUTICAL MILES TRAVELED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	12,084.733	402.824	153,350.682
CH-60 SERVICES CVN	30	11,644.883	388.163	15,369.594
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		3,224	1	3,224
Within Groups		4,892,888	58	84,360
Total		4,896,112	59	
F		***P-value***		***F-crit***
0.038		***0.846***		***4.007***

ANOVA: SINGLE FACTOR				
PALLETS PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	63.164	2.105	0.025
CH-60 SERVICES CVN	30	65.690	2.190	0.031
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		0.106	1	0.106
Within Groups		1.619	58	0.028
Total		1.725	59	
F		***P-value***		***F-crit***
3.811		***0.056***		***4.007***

ANOVA: SINGLE FACTOR				
WEIGHT PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	120,613.356	4,020.445	77,506.570
CH-60 SERVICES CVN	30	125,610.850	4,187.028	125,546.306
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		416,249	1	416,249
Within Groups		5,888,533	58	101,526
Total		6,304,782	59	
F		***P-value***		***F-crit***
4.100		***0.047***		***4.007***

APPENDIX L: SIMULATION DATA FOR CH-46E AND KMAX MIXED

Rep	Elapsed Time		Fuel Burned		Number of Trips	
	46 works CVN	KMAX works CVN	46 works CVN	KMAX works CVN	46 works CVN	KMAX works CVN
1	141.8458	141.4862	3901.0723	3933.8165	302	314
2	141.3810	145.0292	3935.5196	3963.0289	293	351
3	156.4787	151.1156	4208.6747	4230.7130	371	333
4	151.1283	145.1037	4085.5966	4058.1674	377	326
5	146.3702	144.7274	4065.3596	4025.3342	337	335
6	145.6263	142.1419	3994.0655	3702.0296	349	316
7	145.1849	145.8325	4063.1913	4068.8134	325	374
8	157.1057	150.9713	4389.8803	4225.7553	451	397
9	159.7230	153.0324	4337.6659	4280.4363	475	412
10	144.4341	140.7124	4043.5696	3813.0959	287	312
11	147.7939	148.3163	4116.0615	4145.5613	326	378
12	157.2625	152.3959	4403.3490	4265.9553	451	311
13	145.7913	147.9562	4060.4267	4141.6791	315	365
14	152.5123	152.4543	4256.4785	4036.5575	404	390
15	150.6369	142.9577	4076.4644	4002.0336	375	331
16	142.8716	145.6351	3999.1182	4074.7737	280	314
17	148.4200	142.8493	4152.9924	3763.5751	372	321
18	158.2942	150.5216	4414.1679	4214.0566	451	333
19	143.4447	145.2819	4011.2375	3721.6719	321	335
20	153.4528	149.4829	4290.8118	4179.7402	424	334
21	150.8861	146.9936	4221.0684	3936.9132	379	344
22	148.1374	144.8801	4065.0723	3725.2327	331	365
23	148.8568	146.6824	4166.6522	4105.4175	318	319
24	143.6071	153.0828	3967.9686	4283.7113	281	314
25	161.7726	143.2197	4524.9491	3800.7539	451	310
26	155.6965	141.7226	4357.0681	3950.8047	408	313
27	143.4553	151.6179	4009.0336	4239.5154	293	384
28	165.3829	145.2802	4497.0217	3832.2019	451	337
29	144.7303	151.0373	4004.5315	4227.5455	313	358
30	149.8198	152.3949	4188.6349	4265.9109	385	408

Rep	NMiles		Pallets Per Lift		Weight Per Lift	
	46 works CVN	KMAX works CVN	46 works CVN	KMAX works CVN	46 works CVN	KMAX works CVN
1	215.4824	246.0372	2.0571	2.0971	3954.5605	4031.3481
2	204.9714	335.7148	2.0000	2.2143	3823.3355	4211.2661
3	478.9304	379.3530	1.9375	2.0280	3554.1725	3785.7856
4	402.1038	328.5108	2.1485	2.2041	4137.3458	4308.3182
5	265.4067	342.7940	1.7561	2.3226	3434.0909	4487.7216
6	338.5171	281.8339	2.2500	2.3736	4211.1942	4375.6038
7	266.8573	370.5661	2.2979	2.1700	4395.8157	4100.0142
8	485.6364	535.8144	2.2245	2.2708	4236.3136	4220.8310
9	568.1905	596.7687	2.0865	2.3191	4111.9677	4276.8766
10	233.5922	277.7994	2.1386	2.5116	4153.2214	4888.7797
11	307.6136	430.5980	2.1386	2.2604	4214.2574	4301.6262
12	660.5352	329.7192	2.0762	2.1176	3992.0136	4077.8560
13	255.9002	386.0055	2.0000	2.2737	3772.7117	4289.4661
14	354.2360	454.8834	2.1818	2.5233	4119.8632	4932.9349
15	375.2371	264.1370	2.2604	2.1939	4370.3060	4281.6424
16	326.8716	263.3905	2.1600	1.8947	3978.8006	3590.5952
17	345.6211	291.6320	2.0377	2.1939	3947.2298	4238.9415
18	582.4658	337.9955	2.2245	2.3085	4256.9187	4360.1395
19	240.3326	437.2996	2.1386	2.4545	3953.3005	4713.5809
20	461.9417	405.3028	2.3587	2.2041	4570.4345	4196.6762
21	341.2293	294.1034	1.9035	2.0571	3600.6793	3920.1693
22	293.6549	330.6970	1.8151	2.3736	3432.5133	4691.9541
23	327.4719	327.7254	2.2979	2.1485	4412.3106	4101.4478
24	188.2963	254.4358	2.0971	1.9727	4128.7305	3778.7503
25	658.4489	258.2061	2.2474	2.2979	4232.7942	4543.7812
26	404.5413	226.1912	2.0762	2.1717	4072.0211	4258.4454
27	194.7583	425.6329	2.0377	2.5833	3883.7749	4972.6621
28	843.2043	304.7210	2.2708	2.1176	4261.6352	4081.8739
29	287.6178	613.7687	1.6744	2.4270	3280.3467	4472.2681
30	325.9680	576.3917	1.8235	2.5349	3586.0286	4814.3360

APPENDIX M: ANOVA TABLES FOR CH-46E AND KMAX MIXED

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	4,502.103	150.070	41.350
KMAX SERVICES CVN	30	4,414.916	147.164	15.439
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		126.694	1	126.694
Within Groups		1,646.880	58	28.394
Total		1,773.574	59	
F		***P-value***		***F-crit***
4.462		***0.039***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	124,807.704	4,160.257	29,977.334
KMAX SERVICES CVN	30	121,214.802	4,040.493	35,293.092
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		215,149	1	215,149
Within Groups		1,892,842	58	32,635
Total		2,107,991	59	
F		***P-value***		***F-crit***
6.593		***0.013***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	10,896	363.200	3,659.545
KMAX SERVICES CVN	30	10,334	344.467	997.085
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		5,264.067	1	5,264.067
Within Groups		134,462.267	58	2,318.315
Total		139,726.333	59	
F		***P-value***		***F-crit***
2.271		***0.137***		***4.007***

ANOVA: SINGLE FACTOR				
NAUTICAL MILES TRAVELED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	11,235.634	374.521	24,859.179
KMAX SERVICES CVN	30	10,908.029	363.601	11,252.721
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		1,788	1	1,788
Within Groups		1,047,245	58	18,055
Total		1,049,033	59	
F		***P-value***		***F-crit***
0.099		***0.754***		***4.007***

ANOVA: SINGLE FACTOR				
PALLETS PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	62.717	2.091	0.029
KMAX SERVICES CVN	30	67.620	2.254	0.029
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		0.401	1	0.401
Within Groups		1.681	58	0.029
Total		2.082	59	
F		***P-value***		***F-crit***
13.827		***0.000***		***4.007***

ANOVA: SINGLE FACTOR				
WEIGHT PER LIFT				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-46E SERVICES CVN	30	120,078.688	4,002.623	103,748.427
KMAX SERVICES CVN	30	129,305.692	4,310.190	116,655.616
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		1,418,960	1	1,418,960
Within Groups		6,391,717	58	110,202
Total		7,810,667	59	
F		***P-value***		***F-crit***
12.876		***0.001***		***4.007***

APPENDIX N: SIMULATION DATA FOR CH-46E & CH-60 VERSUS CH-46E & KMAX

(CH-60 SERVICING CVN VERSUS KMAX SERVICING CVN)

Rep	**Elapsed Time**		**Fuel Burned**		**Number of Trips**	
	60 works CVN	KMAX works CVN	60 works CVN	KMAX works CVN	60 works CVN	KMAX works CVN
1	144.8082	141.4862	5790.2668	3933.8165	332	314
2	143.3015	145.0292	5728.6111	3963.0289	317	351
3	149.1310	151.1156	5848.1525	4230.7130	363	333
4	149.0585	145.1037	5947.0813	4058.1674	333	326
5	140.8756	144.7274	5624.3197	4025.3342	259	335
6	147.8666	142.1419	5912.8065	3702.0296	391	316
7	146.3378	145.8325	5845.5298	4068.8134	350	374
8	142.3421	150.9713	5663.4364	4225.7553	290	397
9	146.3445	153.0324	5850.3489	4280.4363	325	412
10	146.6756	140.7124	5864.8886	3813.0959	330	312
11	146.6986	148.3163	5854.4548	4145.5613	346	378
12	158.2639	152.3959	6326.2793	4265.9553	336	311
13	150.1044	147.9562	5985.6230	4141.6791	334	365
14	158.7243	152.4543	6345.2965	4036.5575	410	390
15	148.6716	142.9577	5943.5558	4002.0336	296	331
16	146.0143	145.6351	5840.5106	4074.7737	276	314
17	153.8816	142.8493	6152.1195	3763.5751	310	321
18	149.1139	150.5216	5960.5199	4214.0566	325	333
19	149.6612	145.2819	5984.4311	3721.6719	337	335
20	150.6205	149.4829	6016.6761	4179.7402	411	334
21	154.5528	146.9936	6081.4335	3936.9132	360	344
22	146.0540	144.8801	5838.6218	3725.2327	322	365
23	156.6204	146.6824	6253.2070	4105.4175	470	319
24	151.5893	153.0828	6060.1837	4283.7113	379	314
25	143.2869	143.2197	5726.8314	3800.7539	318	310
26	147.0197	141.7226	5865.6771	3950.8047	307	313
27	149.1707	151.6179	5947.7421	4239.5154	349	384
28	151.5623	145.2802	6061.3935	3832.2019	360	337
29	145.2239	151.0373	5503.4409	4227.5455	314	358
30	145.6450	152.3949	5805.8526	4265.9109	302	408

(CH-60 SERVICING CVN VERSUS KMAX SERVICING CVN)

Rep	NMiles		Pallets Per Lift		Weight Per Lift	
	60 works CVN	KMAX works CVN	60 works CVN	KMAX works CVN	60 works CVN	KMAX works CVN
1	482.5852	246.0372	2.1485	2.0971	4120.0876	4031.3481
2	309.4694	335.7148	2.3478	2.2143	4361.1653	4211.2661
3	363.0041	379.3530	2.2143	2.0280	4277.1410	3785.7856
4	271.5019	328.5108	1.9375	2.2041	3733.3137	4308.3182
5	191.7259	342.7940	2.2737	2.3226	4388.3633	4487.7216
6	433.6103	281.8339	2.1373	2.3736	3933.2667	4375.6038
7	388.0867	370.5661	2.2041	2.1700	4235.5580	4100.0142
8	326.9319	535.8144	2.5116	2.2708	4766.7991	4220.8310
9	262.4817	596.7687	2.1176	2.3191	4035.8655	4276.8766
10	336.2915	277.7994	2.4270	2.5116	4701.4697	4888.7797
11	304.1949	430.5980	2.0971	2.2604	4002.0862	4301.6262
12	467.9796	329.7192	2.1683	2.1176	4043.9346	4077.8560
13	478.0414	386.0055	2.4270	2.2737	4682.8521	4289.4661
14	503.8380	454.8834	1.8879	2.5233	3610.4382	4932.9349
15	281.2235	264.1370	1.8534	2.1939	3579.3678	4281.6424
16	286.1782	263.3905	2.2041	1.8947	4059.5578	3590.5952
17	338.1444	291.6320	2.1386	2.1939	4137.3742	4238.9415
18	262.3824	337.9955	1.8632	2.3085	3601.5428	4360.1395
19	436.7049	437.2996	2.1919	2.4545	4103.7929	4713.5809
20	521.9478	405.3028	2.1800	2.2041	4257.1418	4196.6762
21	520.5713	294.1034	2.3118	2.0571	4435.9626	3920.1693
22	261.4001	330.6970	2.0472	2.3736	3780.9685	4691.9541
23	782.4706	327.7254	1.9550	2.1485	3784.8098	4101.4478
24	578.2101	254.4358	2.4659	1.9727	4842.6247	3778.7503
25	325.9675	258.2061	2.1818	2.2979	4229.2865	4543.7812
26	277.4500	226.1912	2.3736	2.1717	4614.9921	4258.4454
27	391.5406	425.6329	2.1584	2.5833	4050.0354	4972.6621
28	515.3562	304.7210	2.2500	2.1176	4316.0194	4081.8739
29	382.7837	613.7687	2.3889	2.4270	4680.4501	4472.2681
30	362.8090	576.3917	2.2268	2.5349	4244.5824	4814.3360

APPENDIX O: ANOVA TABLES FOR CH-46E & CH-60 VERSUS CH-46E & KMAX

ANOVA: SINGLE FACTOR				
ELAPSED TIME				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	4,459.221	148.641	19.763
KMAX SERVICES CVN	30	4,414.916	147.164	15.439
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		32.715	1	32.715
Within Groups		1,020.864	58	17.601
Total		1,053.579	59	
F		***P-value***		***F-crit***
1.859		***0.178***		***4.007***

ANOVA: SINGLE FACTOR				
FUEL CONSUMED				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	177,629.292	5,920.976	36,808.261
KMAX SERVICES CVN	30	121,214.802	4,040.493	35,293.092
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		53,043,245	1	53,043,245
Within Groups		2,090,939	58	36,050
Total		55,134,184	59	
F		***P-value***		***F-crit***
1,471.352		***6.53E-43***		***4.007***

ANOVA: SINGLE FACTOR				
NUMBER OF TRIPS				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	10,152	338.400	1,851.559
KMAX SERVICES CVN	30	10,334	344.467	977.085
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		552.067	1	552.067
Within Groups		82,030.667	58	1,414.322
Total		82,582.733	59	
F		***P-value***		***F-crit***
0.390		***0.535***		***4.007***

ANOVA: SINGLE FACTOR **NAUTICAL MILES TRAVELED**				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	11,644.883	388.163	15,369.594
KMAX SERVICES CVN	30	10,908.029	363.601	11,252.721
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		9,049.218	1	9,049.218
Within Groups		772,047.157	58	13,311.158
Total		781,096.375	59	
F		***P-value***		***F-crit***
0.680		***0.413***		***4.007***

ANOVA: SINGLE FACTOR **PALLETS PER LIFT**				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	65.690	2.190	0.031
KMAX SERVICES CVN	30	67.620	2.254	0.029
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		0.062	1	0.062
Within Groups		1.729	58	0.030
Total		1.791	59	
F		***P-value***		***F-crit***
2.082		***0.154***		***4.007***

ANOVA: SINGLE FACTOR **WEIGHT PER LIFT**				
SUMMARY				
GROUPS	*COUNT*	*SUM*	*AVERAGE*	*VARIANCE*
CH-60 SERVICES CVN	30	125,610.850	4,187.028	125,546.306
KMAX SERVICES CVN	30	129,305.692	4,310.190	116,655.616
ANOVA				
Source of Variation		*SS*	*df*	*MS*
Between Groups		227,530	1	227,530
Within Groups		7,023,855	58	121,100
Total		7,251,386	59	
F		***P-value***		***F-crit***
1.879		***0.176***		***4.007***

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